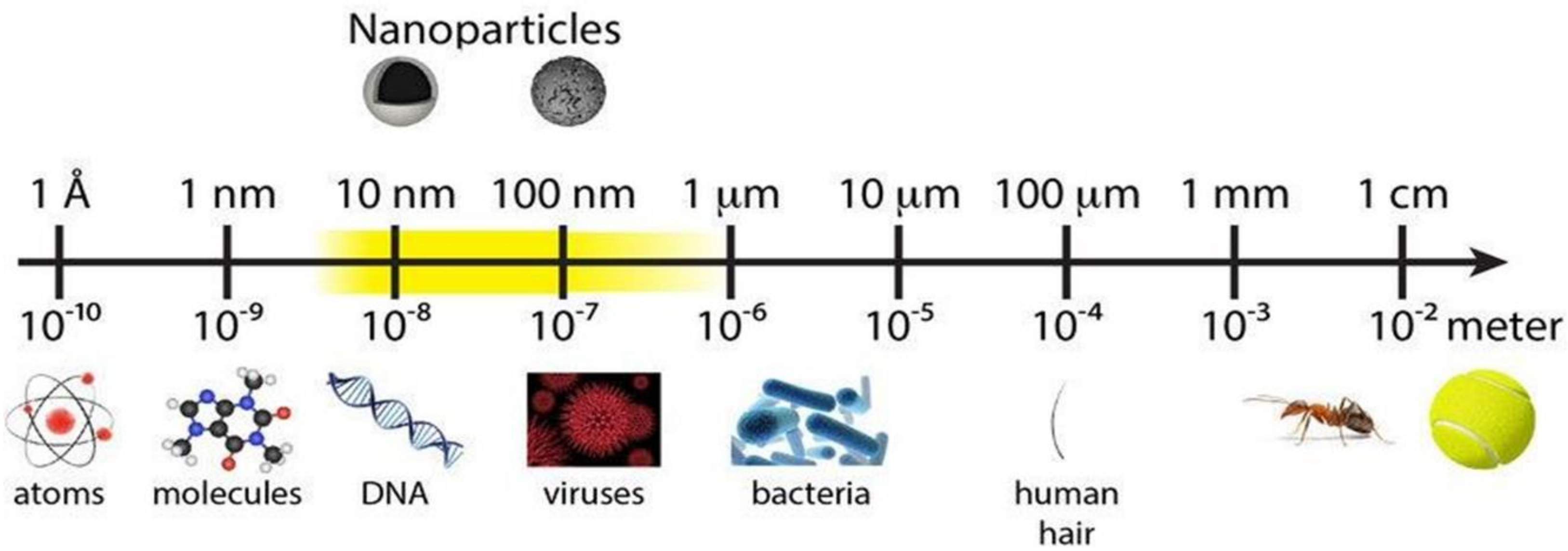
Is this Nano?

Nanotechnology is a "*system of innovative methods to control and manipulate matter at near-atomic scale to produce new materials, structures, and devices*".

↓

Nanomaterials (NMs)

Materials in the range of 100 nm are considered to be nanoparticles. They exhibit a wide range of properties, including optical, electrical, catalytic, magnetic, and biological activity.



Metal nanoparticles

Metal nanoparticles are tiny particles of metals that have dimensions typically in the range of 1 to 100 nanometers. At this scale, materials exhibit unique physical, chemical, and optical properties that differ significantly from their bulk counterparts due to quantum effects and a high surface area-to-volume ratio. Here are key features and details about metal nanoparticles:

Characteristics of Metal Nanoparticles

1.Size and Shape:

1. Their nanoscale size gives them distinct properties.
2. They can have various shapes like spheres, rods, cubes, or plates, which influence their behavior and applications.

2.High Surface Area:

1. Due to their small size, metal nanoparticles have a high ratio of surface atoms compared to bulk materials, enhancing their reactivity.

3.Optical Properties:

1. Metal nanoparticles exhibit localized surface plasmon resonance (LSPR), where electrons resonate with light at specific wavelengths, leading to vibrant colors (e.g., gold nanoparticles appearing red or purple).

4.Quantum Effects:

1. The electronic properties of metal nanoparticles are size-dependent, making them useful in catalysis, electronics, and quantum dot technologies.

Common Types of Metal Nanoparticles

- **Gold (Au) Nanoparticles**: Widely used in medical imaging, drug delivery, and as catalysts.
- **Silver (Ag) Nanoparticles**: Known for their antimicrobial properties, used in coatings and textiles.
- **Platinum (Pt) Nanoparticles**: Used in fuel cells and as catalysts in chemical reactions.
- **Iron (Fe) Nanoparticles**: Often employed in environmental remediation and magnetic applications.

Synthesis Methods

- **Physical Methods**: Laser ablation, evaporation-condensation techniques.
- **Chemical Methods**: Reduction of metal salts in solution using reducing agents like citrate or borohydride.
- **Biological Methods**: Utilizing plant extracts, bacteria, or fungi for eco-friendly synthesis.

Applications

1.Catalysis:

1. Metal nanoparticles accelerate chemical reactions due to their high reactivity and surface area.

2.Biomedical Uses:

1. Targeted drug delivery, cancer treatment, imaging, and biosensors.

3.Environmental Remediation:

1. Removal of pollutants or heavy metals from water and soil.

4.Electronics:

1. Used in conductive inks, circuits, and memory devices.

5.Optics and Photonics:

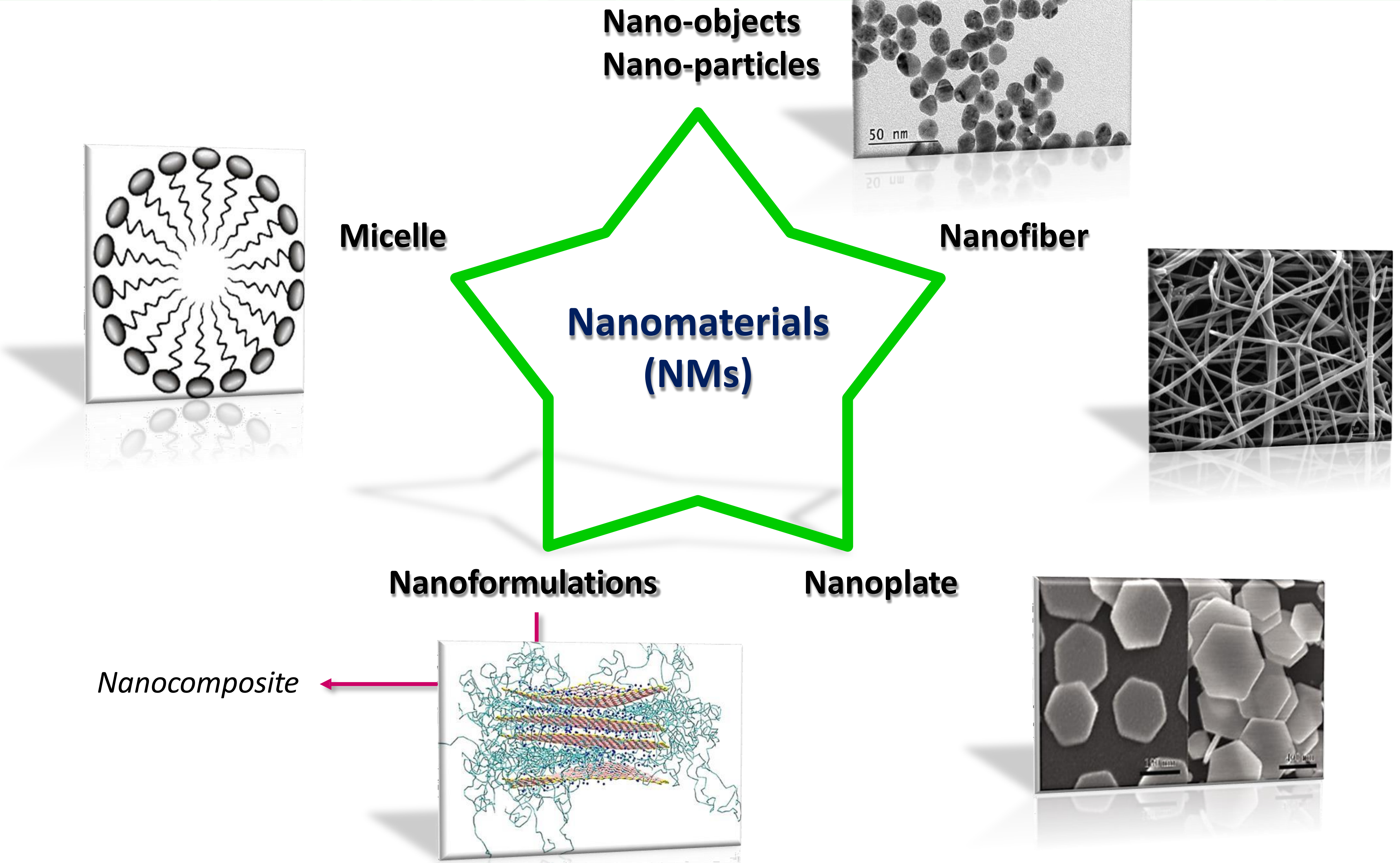
1. Enhancement of optical devices and sensors using their plasmonic properties.

Safety and Environmental Considerations

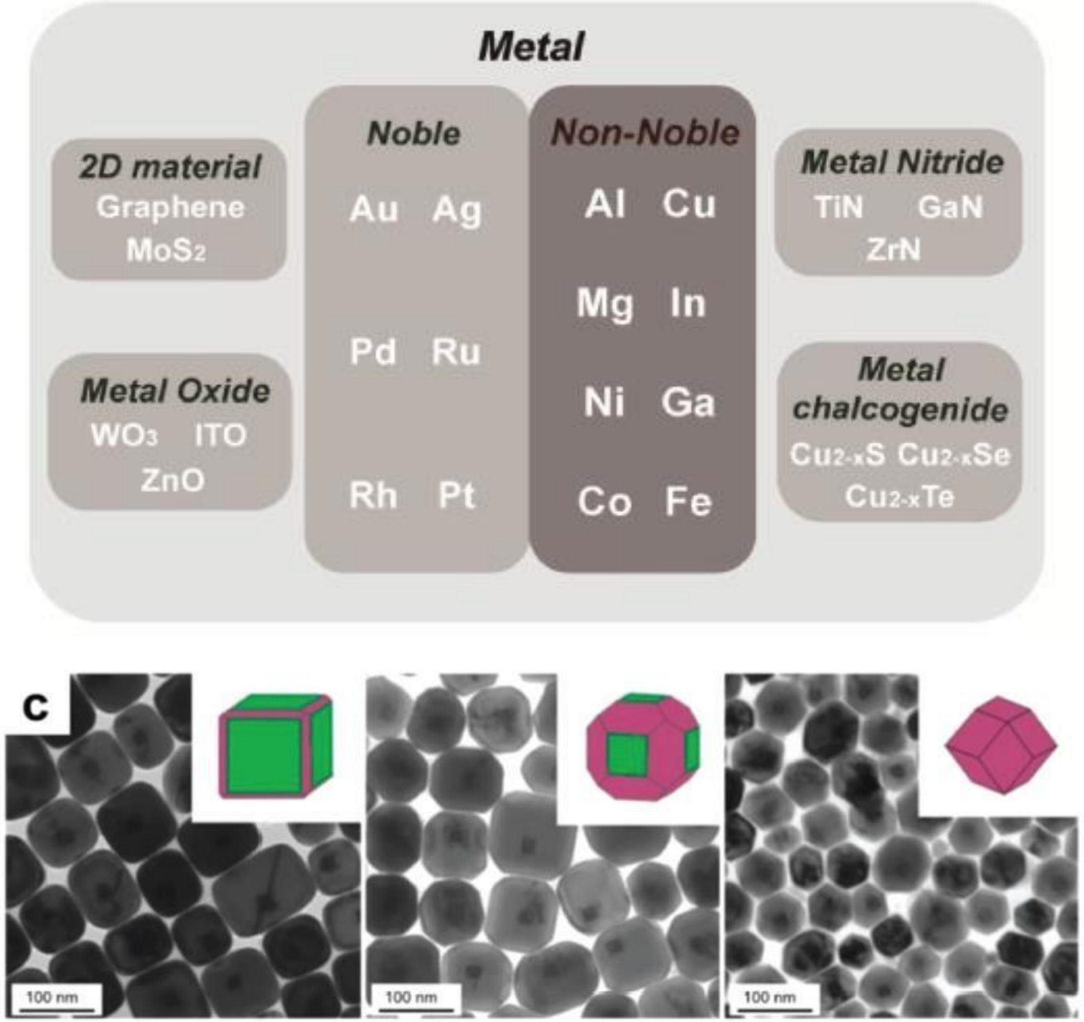
While metal nanoparticles have exciting applications, their potential toxicity and environmental impact are subjects of ongoing research. Careful assessment and regulation are essential to balance benefits with risks.

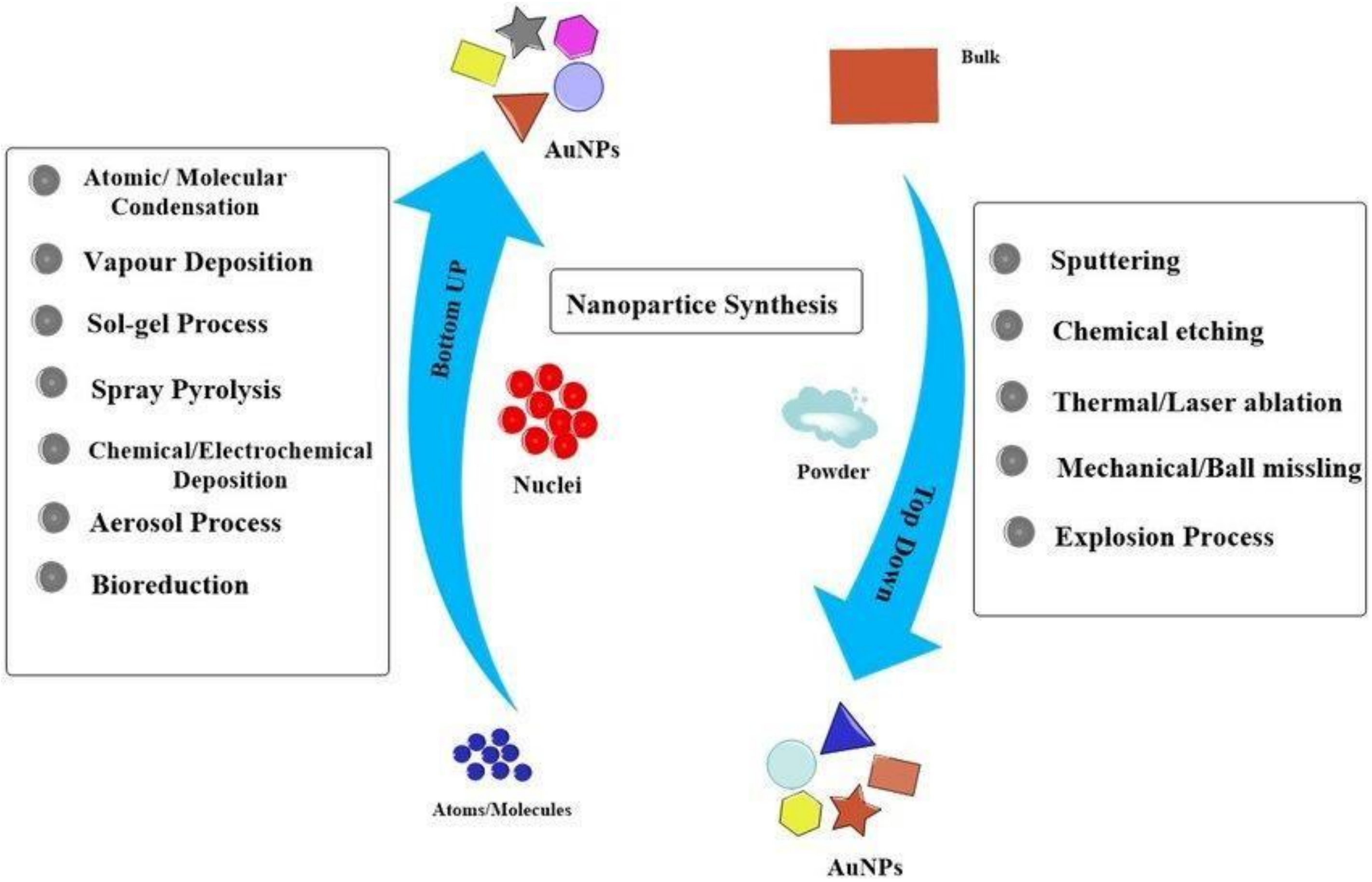
Metal nanoparticles are a frontier of nanotechnology with immense potential across industries, driven by their unique properties at the nanoscale.

Nanomaterials

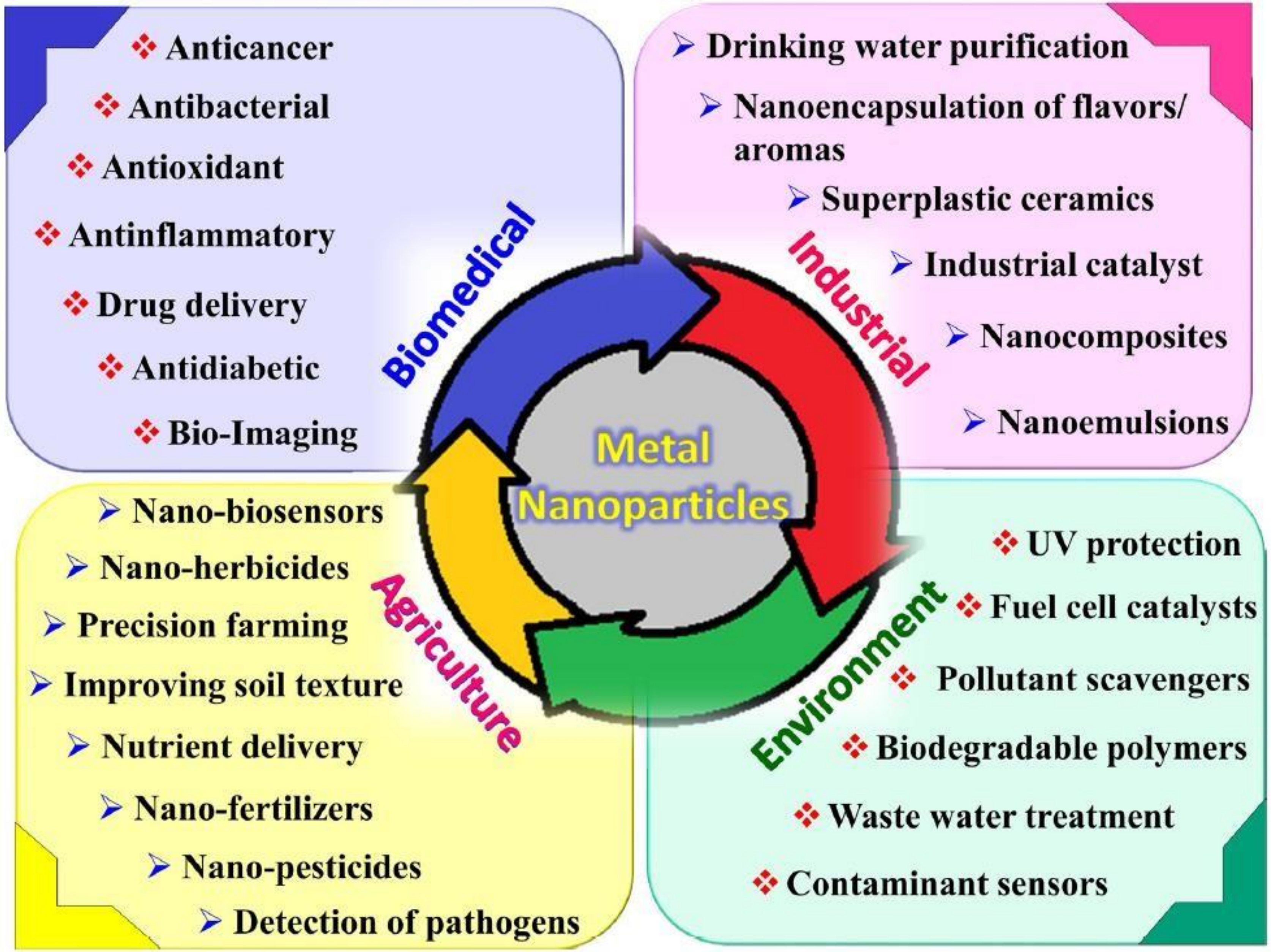


Metal based Nanoparticles





Metal Nanoparticles application fields



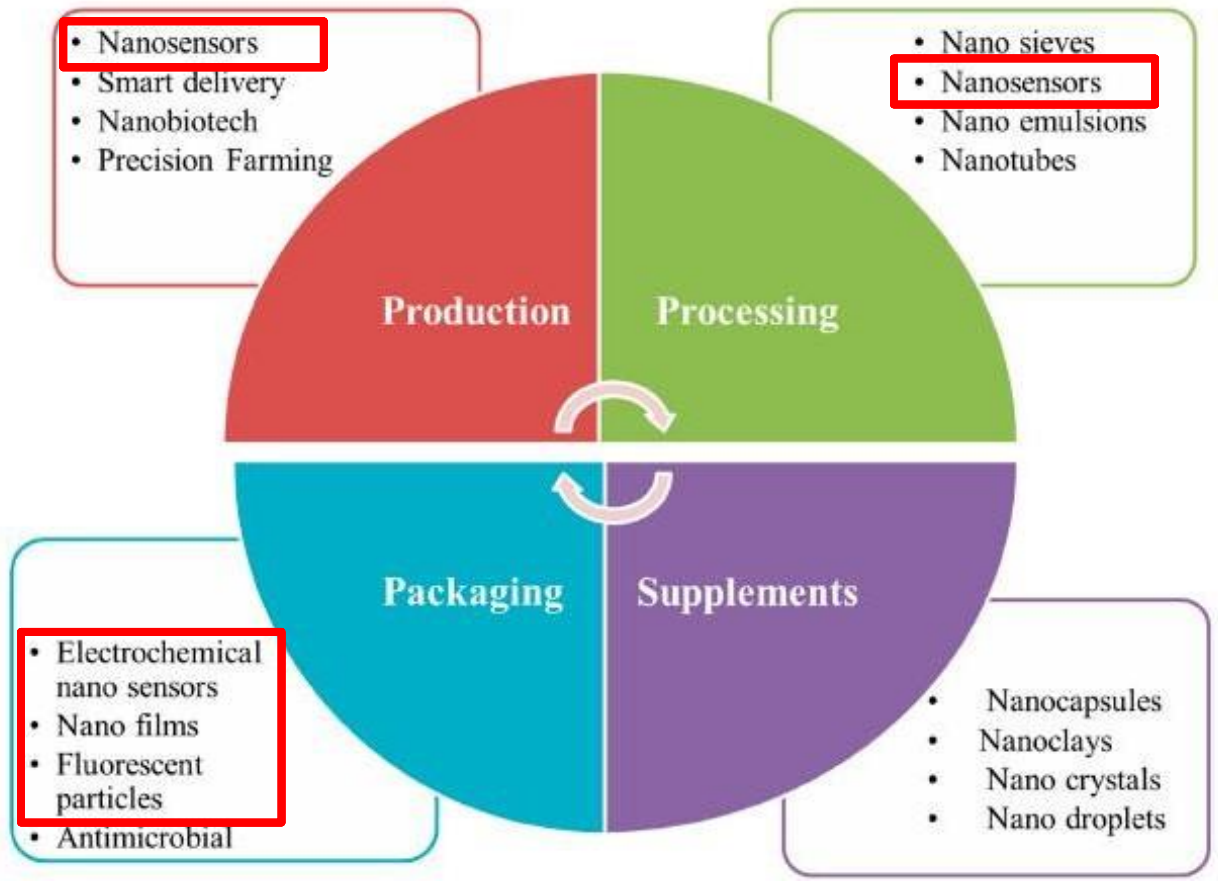
Nanoparticles in food technology, an overview

foods
MDPI

Review

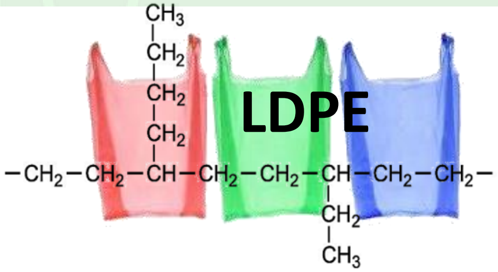
An Overview of the Applications of Nanomaterials and Nanodevices in the Food Industry

Mehwish Shafiq [1], Sumaira Anjum [1,*], Christophe Hano [2], Iram Anjum [1] and Bilal Haider Abbasi [3]



Nanomaterials	Type of Nanomaterials	Applications in Food Industry
Nanoparticles	Ag, ZnO, Mg, SiO_2	Food packaging, oxidation of contaminant, anti-bacterial
Nanosieves	Specific nanoparticles	Removal of pathogens or contaminants
Nanocapsules	Bioactive compounds	Increased efficacy and water solubility, local and controlled release
Nano-emulsions	Tweens or spans; gum arabica or modified starch, soy, caseinate	Food encapsulation, food processing, antimicrobial and storage, stability, colorant
Nanospheres	Starch nanosphere	Food encapsulation, synthetic adhesives
Nanosensors	Aptasensors	Detection of micro-organisms, food deterioration control
Nanocochleates	Coiled Nanoparticles	Enhanced nutritional value of food, antioxidant, food protection and stability
Nanocomposite	$Fe\text{-}Cr/Al_2O_3$ Ni/Al_2O_3	Enhanced shelf life of food, food protection and food packaging
Nanomicelles	Aquanova, novasol	Liquid carrier, enhanced solubility

Nanoparticles application in food technology

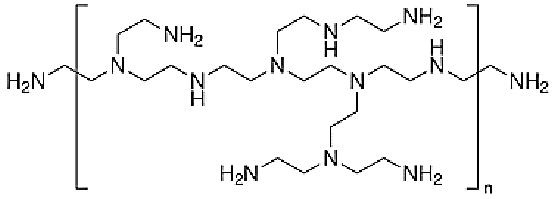


Commercial low-density polyethylene (LDPE) films coated using a layer-by-layer (LbL) technique by alternating the deposition of polyethyleneimine (PEI), poly(acrylic acid) polymer (PAA) solutions and antimicrobial silver nanoparticles (Ag).

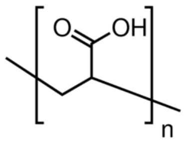
2 different LbL condition

Modified pH (MpH)

PEI pH 9
PAA pH 6,5



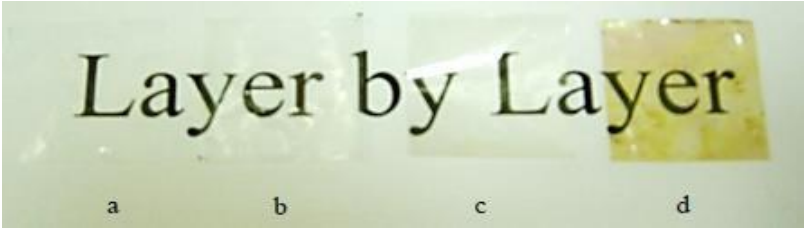
PEI



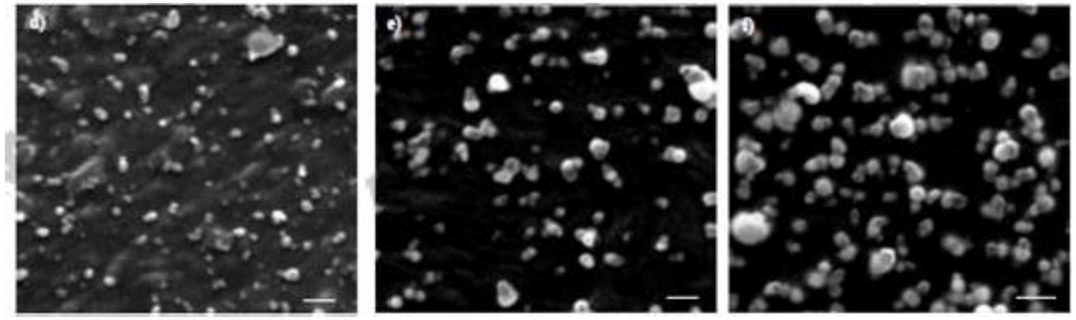
PAA

Non-Modified pH (NMpH)

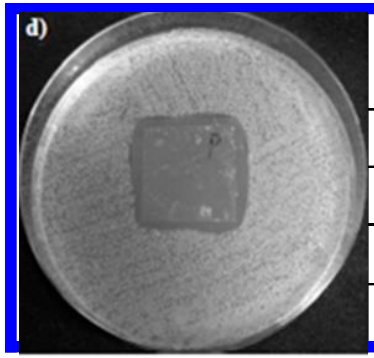
PEI pH 10,5
PAA pH 4



The colour changes of a) LDPE films and b) LDPE LbL coated (3 coatings) films without Ag and c) AgNPs presence on LDPE LbL coated (3 coatings) films immersed in 0,5% $AgNO_3$, or d) AgNPs presence on LDPE LbL coated with (3 coatings) film immersed in 5% $AgNO_3$ and UV/ozone treated for 20 min.

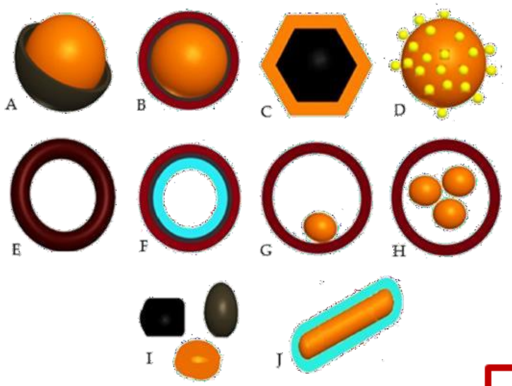


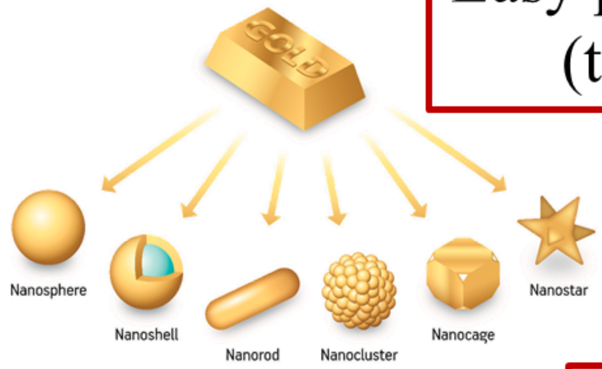
(d) LbL coated (3 coating) immersed in 0,5% $AgNO_3$, (e) LbL coated (3 coatings) immersed in 2% $AgNO_3$; and (f) LbL coated (3 coatings) immersed in 5% $AgNO_3$. Scale bar = 500nm

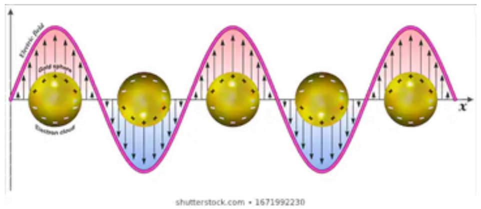


	Inibition zone (mm^2)	
Film	*S. aureus*	*P. fluorescens*
LPDE films	0.00	0.00
LPDE + PEI/PAA (MpH)	350.4 ± 13.30	694.8 ± 19.15
LPDE + PEI/PAA (NMpH)	460.0 ± 25.41	737.0 ± 15.08

Advantages of metal nanoparticles for analytical purposes

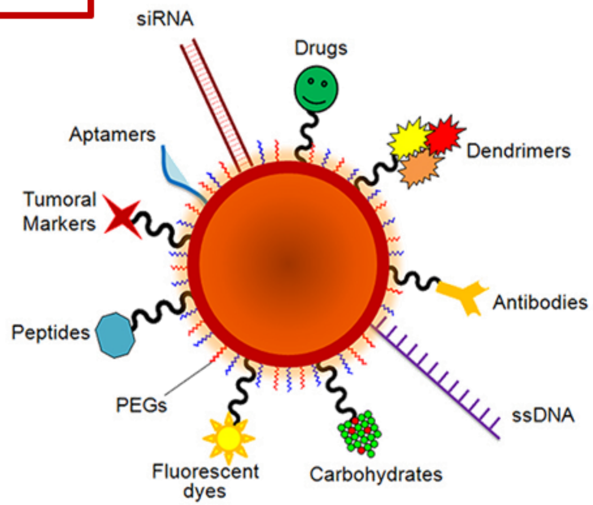






MNPs

- Nano
- High conductivity
- Robust / stable *(Inhert)*
- Surface (Bio)functionalization
- Good biocompatibility
- Easy preparation (tunable)



Localized Surface Plasmon Resonance (LSPR) is a phenomenon where conduction electrons on the surface of metal nanoparticles oscillate collectively in resonance with the electromagnetic field of incident light. This effect occurs in nanoparticles of certain metals, such as gold (Au), silver (Ag), and copper (Cu), when they are illuminated by light of specific wavelengths.

Key Features of LSPR

1. **Localized Nature**:
   The oscillation of electrons is confined to the surface of the nanoparticles due to their small size and interaction with light.
2. **Size and Shape Dependence**:
   The resonance wavelength of LSPR is highly dependent on the size, shape, and composition of the nanoparticles. For example:
   a. Spherical gold nanoparticles typically resonate with red or green light.
   b. Rod-shaped particles may shift the resonance to infrared or other regions.
3. **Material-Specific Behavior**:
   Noble metals like gold and silver exhibit strong LSPR because they have free electrons that can oscillate easily under an electromagnetic field.
4. **Sensitivity to Environment**:
   The LSPR frequency is influenced by the surrounding medium, including the refractive index. This property makes LSPR highly sensitive for detecting changes in the local environment.

Mechanism of LSPR

1. **Interaction with Light**:
   When light strikes a metal nanoparticle, it causes the free conduction electrons (from the metal's conduction band) to oscillate collectively at a specific frequency.
2. **Resonance**:
   If the frequency of light matches the natural oscillation frequency of the electrons, resonance occurs. This amplifies the oscillation and enhances the electromagnetic field around the nanoparticle.
3. **Energy Dissipation**:
   The resonance leads to strong absorption (not as electronic transitions of molecules!) and scattering of light. The absorbed energy can dissipate as heat or radiate as scattered light.

Applications of LSPR

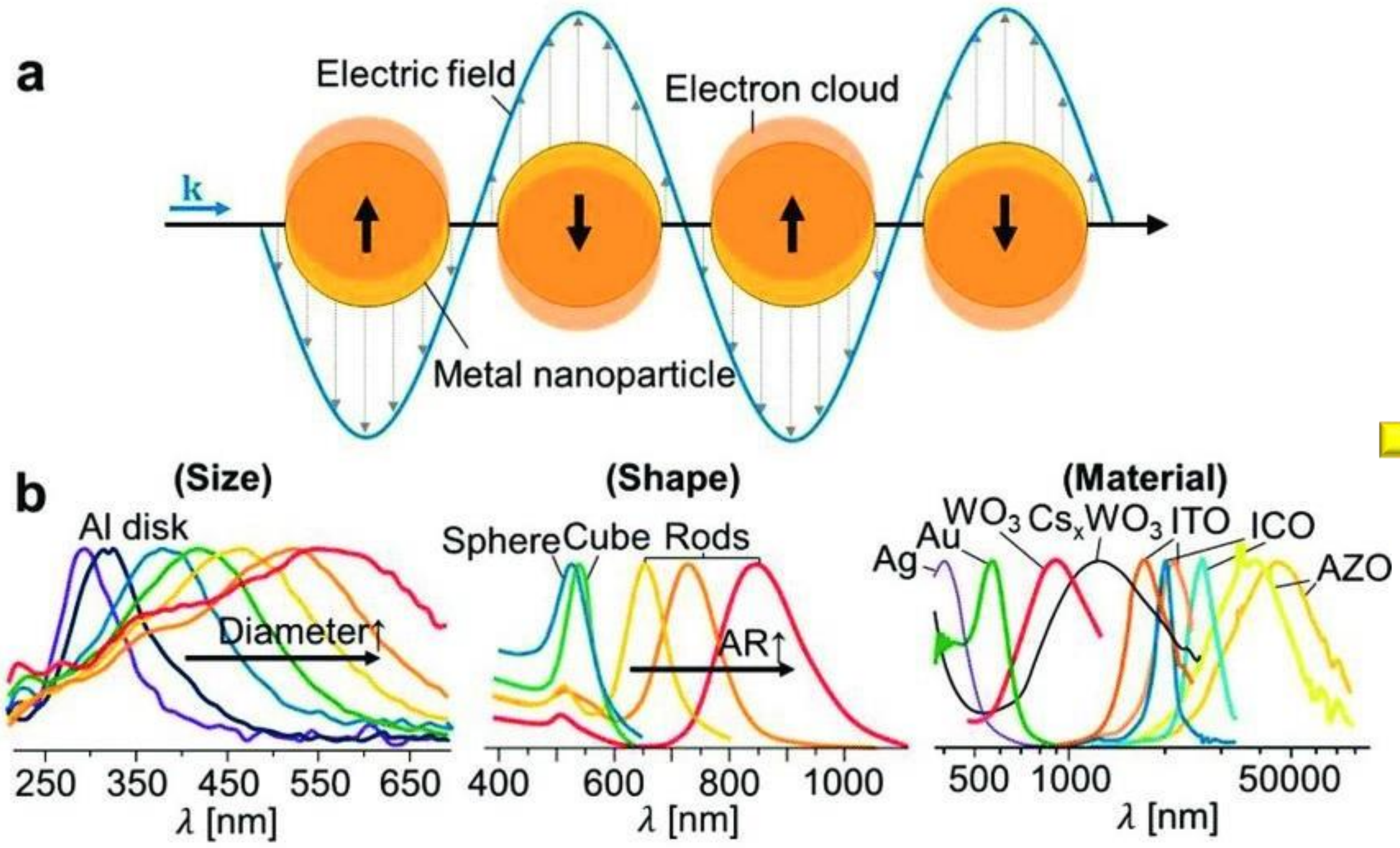
1. **Sensing**:
   Biosensors: Changes in the LSPR frequency can detect biomolecules binding to a nanoparticle's surface.
   Environmental Monitoring: Detecting pollutants or chemical changes in a medium.
2. **Medical Imaging**:
   Enhanced contrast in imaging techniques due to strong light scattering by nanoparticles.
3. **Photothermal Therapy**:
   Gold nanoparticles can absorb light at their LSPR frequency, converting it into heat for targeted cancer treatments.
4. **Catalysis**:
   Enhanced catalytic activity due to the intense localized electromagnetic field at the nanoparticle surface.
5. **Optoelectronic Devices**:
   LSPR enhances light-matter interaction, improving the efficiency of devices like solar cells and LEDs.

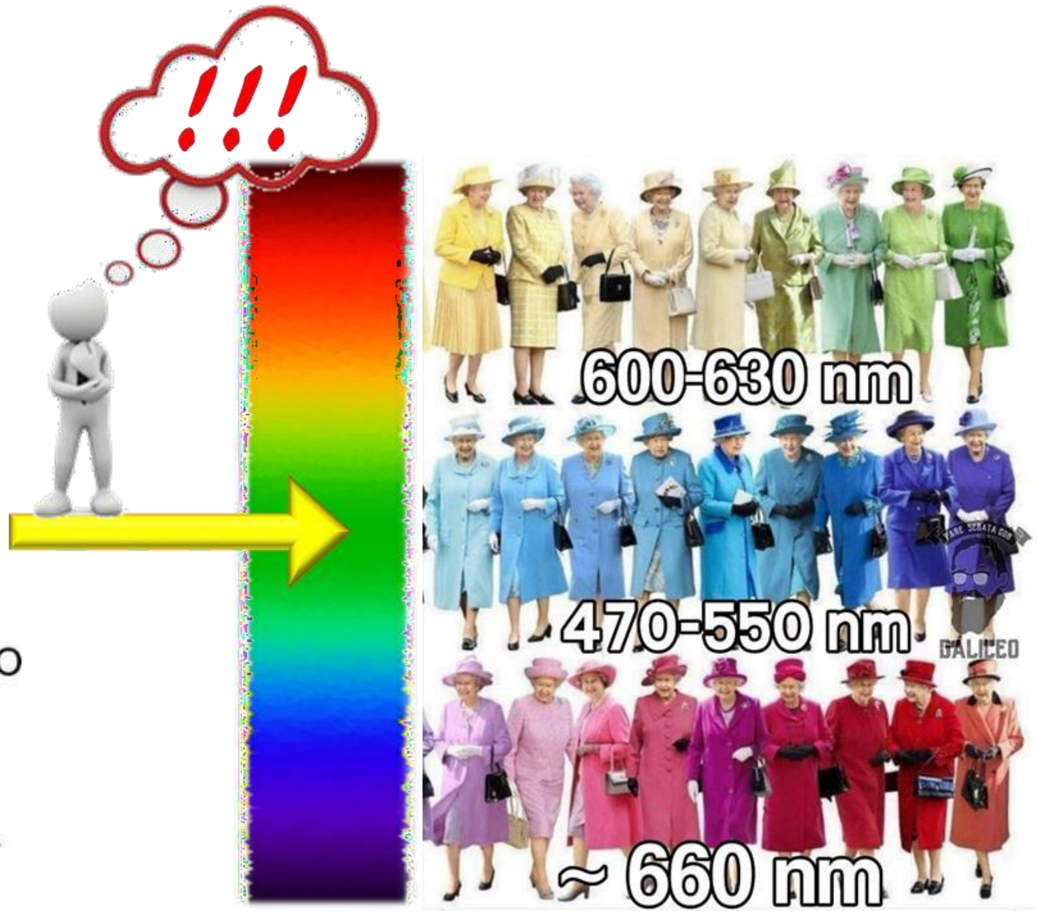
Advantages of LSPR

- High sensitivity to small environmental changes.
- Tunable properties by modifying the nanoparticle size, shape, and material.
- Versatility in biological, chemical, and physical applications.

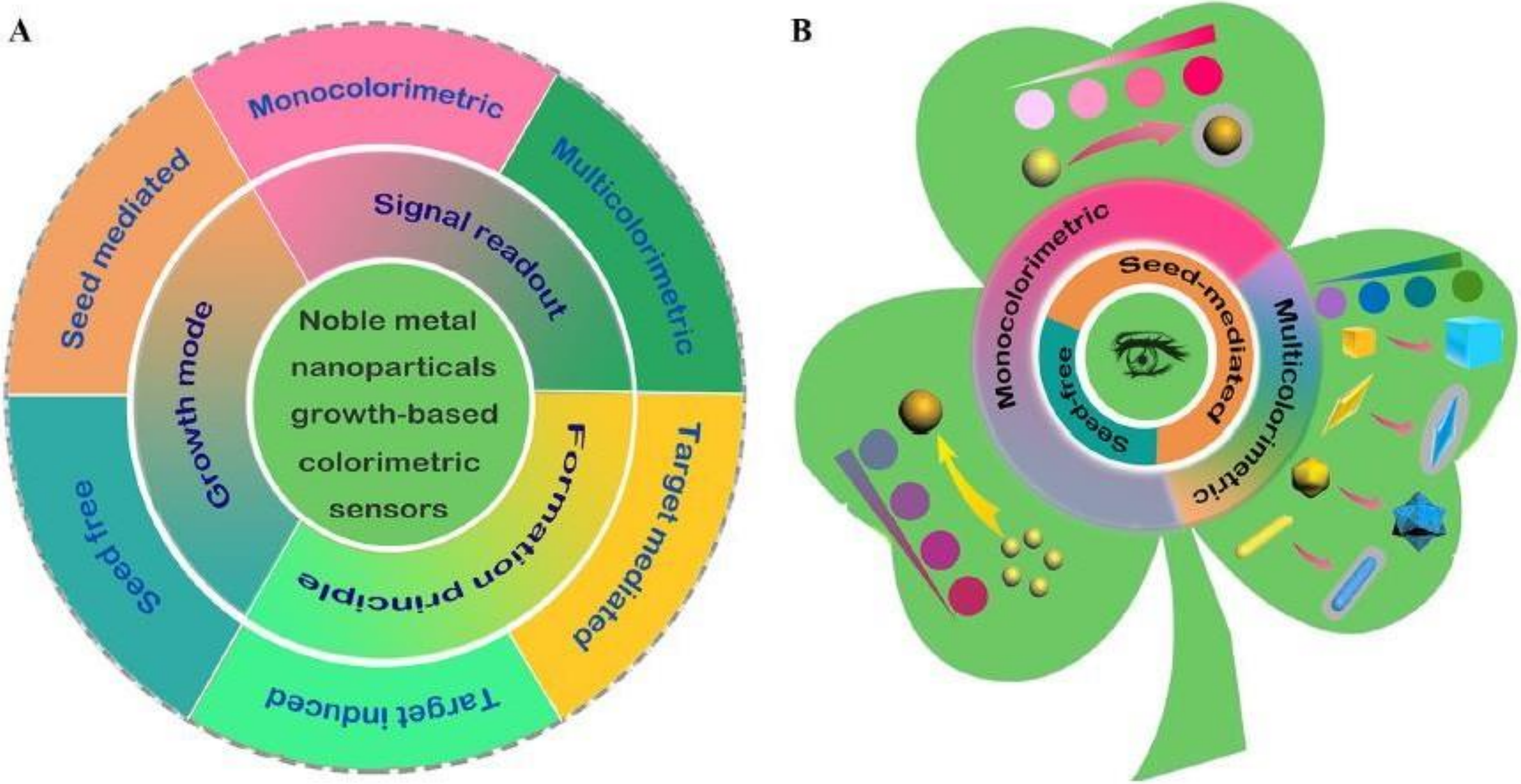
Localized Surface Plasmon Resonance (LSPR)

Principle



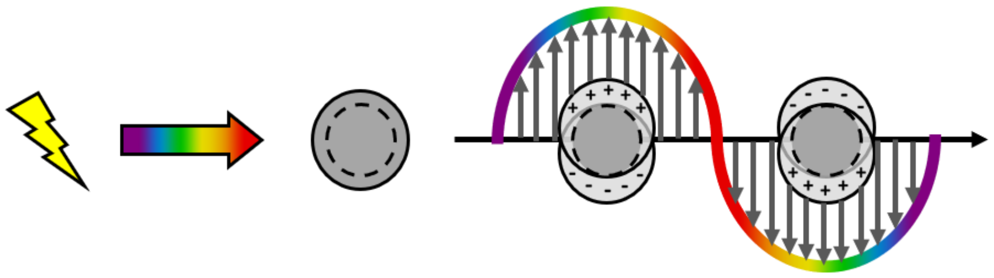


GÉRARD, Davy; GRAY, Stephen K. Aluminium plasmonics. *Journal of Physics D: Applied Physics*, 2014, 48.18: 184001.
CHEN, Huanjun, et al. Shape-and size-dependent refractive index sensitivity of gold nanoparticles. *Langmuir*, 2008, 24.10: 5233-5237.
LOUNIS, Sebastien D., et al. Defect chemistry and plasmon physics of colloidal metal oxide nanocrystals. *The journal of physical chemistry letters*, 2014, 5.9: 1564-1574.

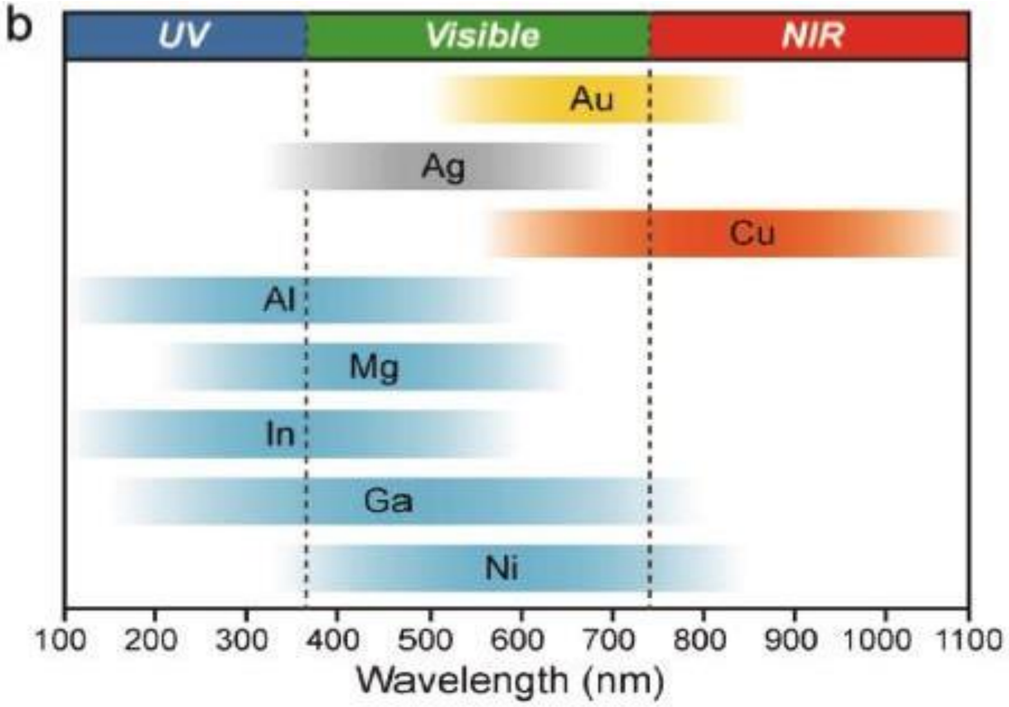


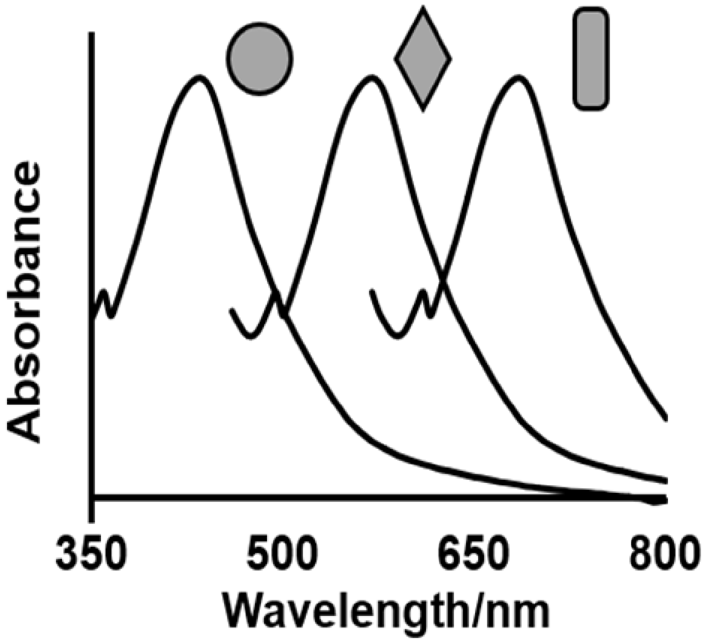
A
Monocolorimetric
Multicolorimetric
Seed mediated
Seed free
Target induced
Target mediated
Signal readout
Growth mode
Formation principle
Noble metal nanoparticals growth-based colorimetric sensors
B
Monocolorimetric
Multicolorimetric
Seed-mediated
Seed-free

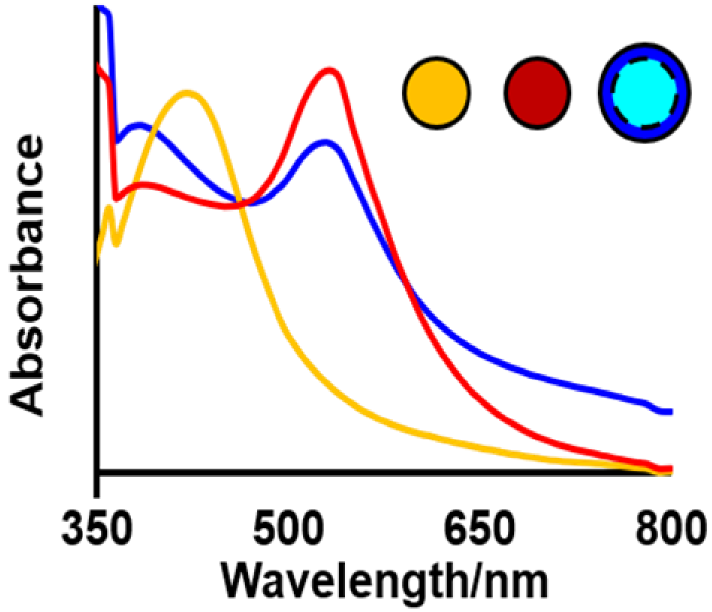
Metal nanoparticles optical key features



Localized Surface
Plasmon
Resonance



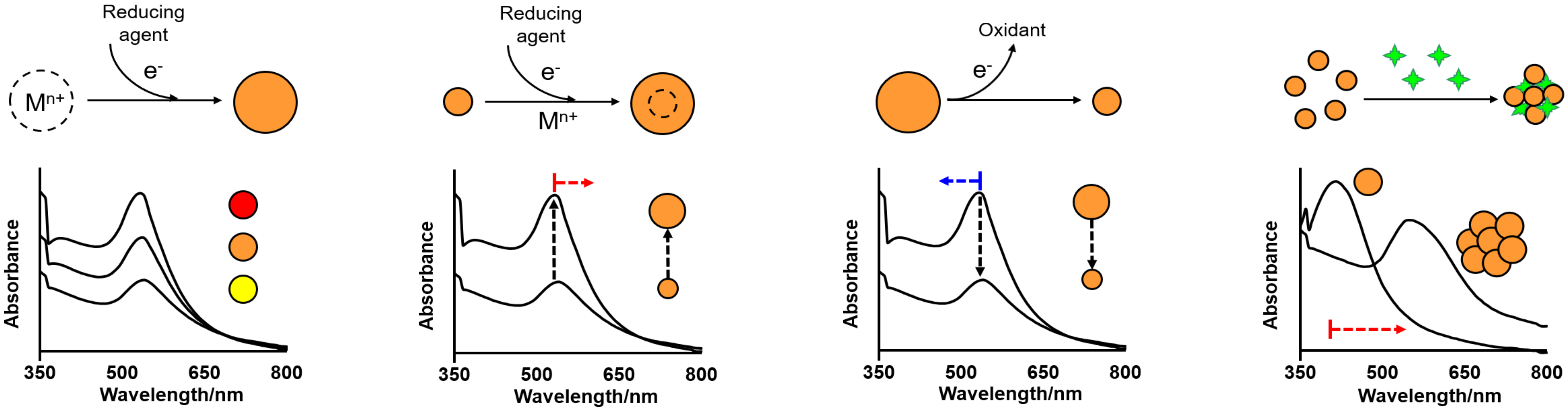




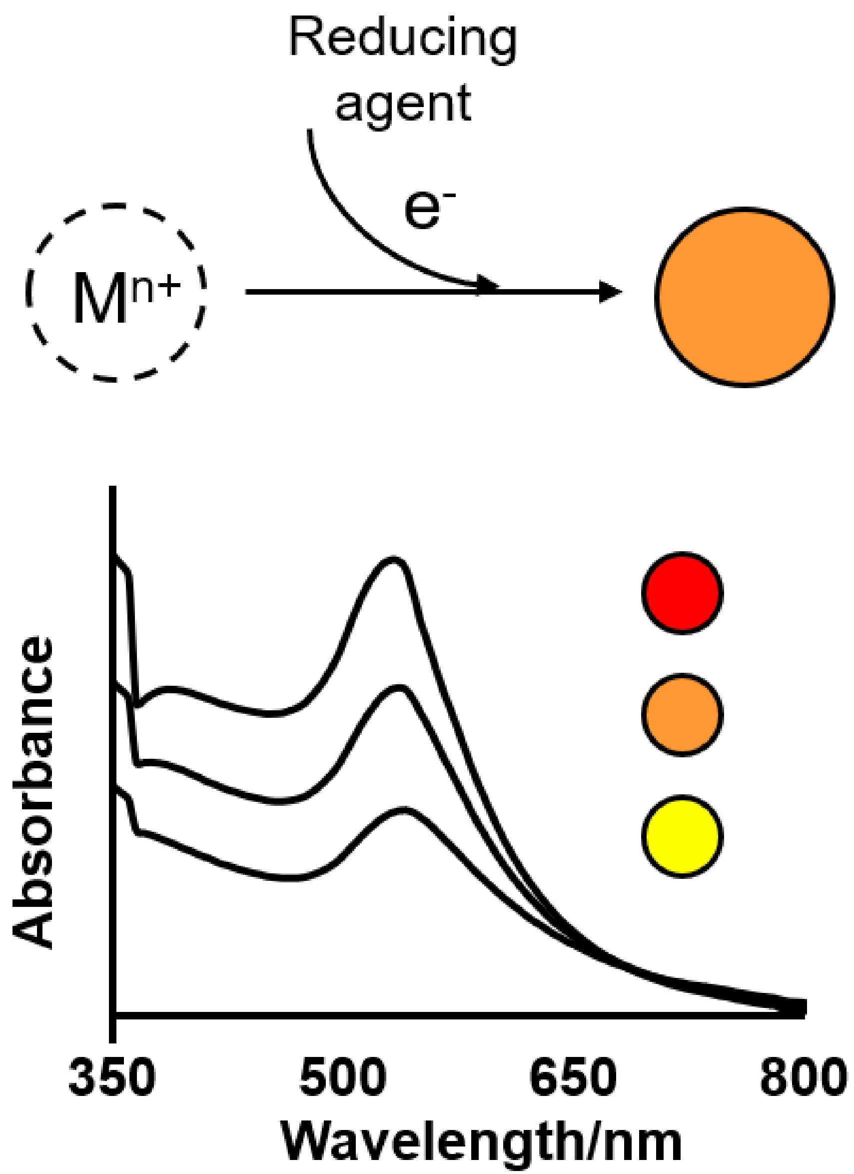
Plasmonic-active nanostructured materials for sensing and biosensing

Colloidal metal nanoparticles based assays

Localized Surface Plasmon Resonance

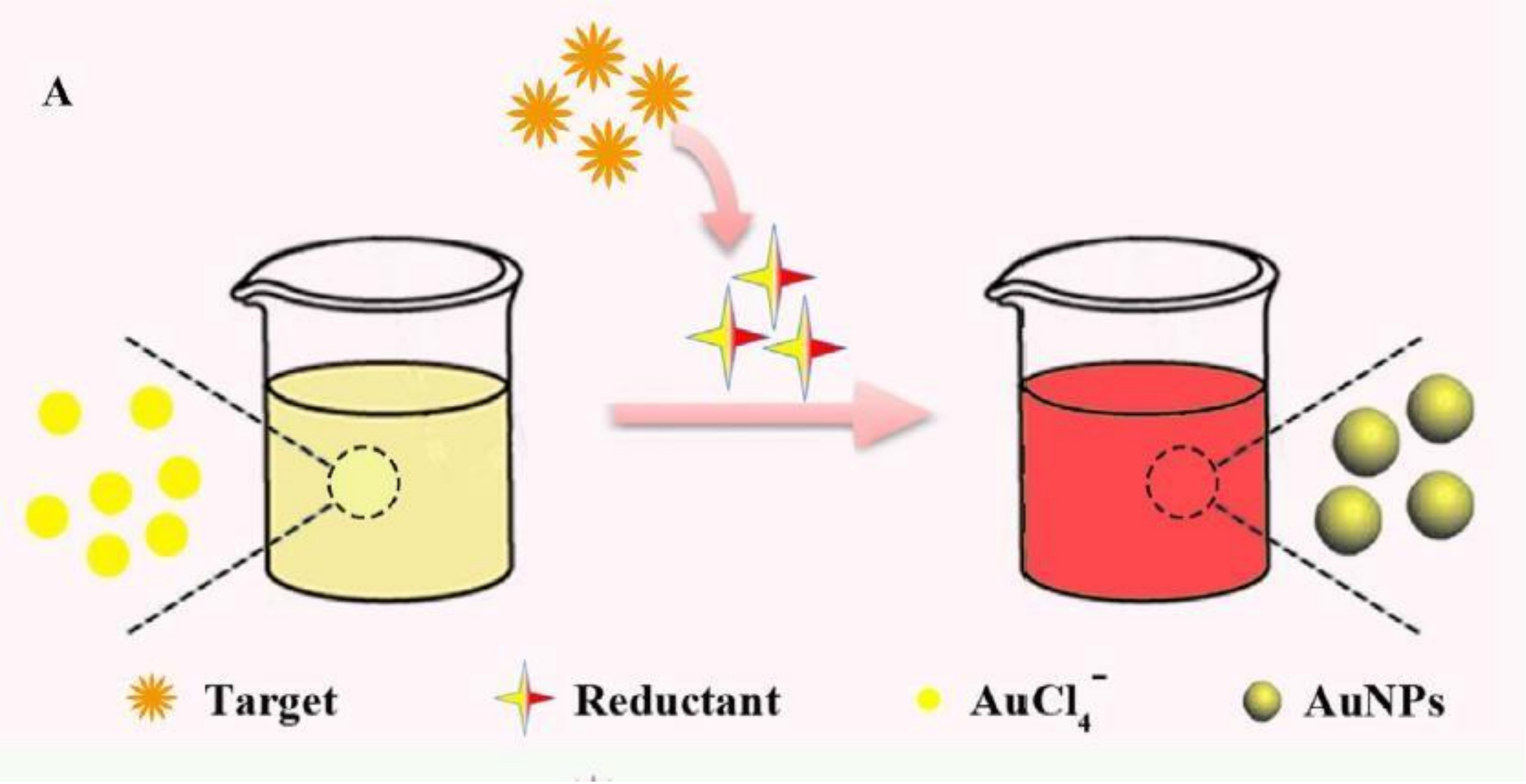


Metal nanoparticles formation



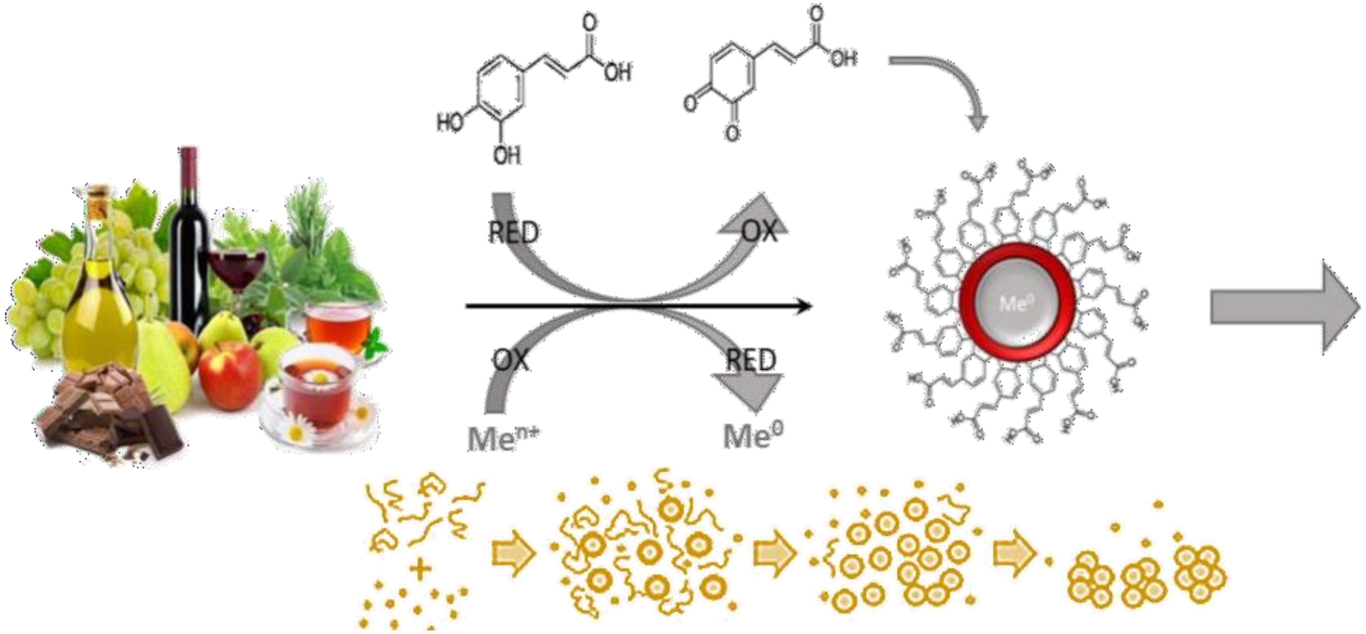
Metal nanoparticles formation.

Main strategy

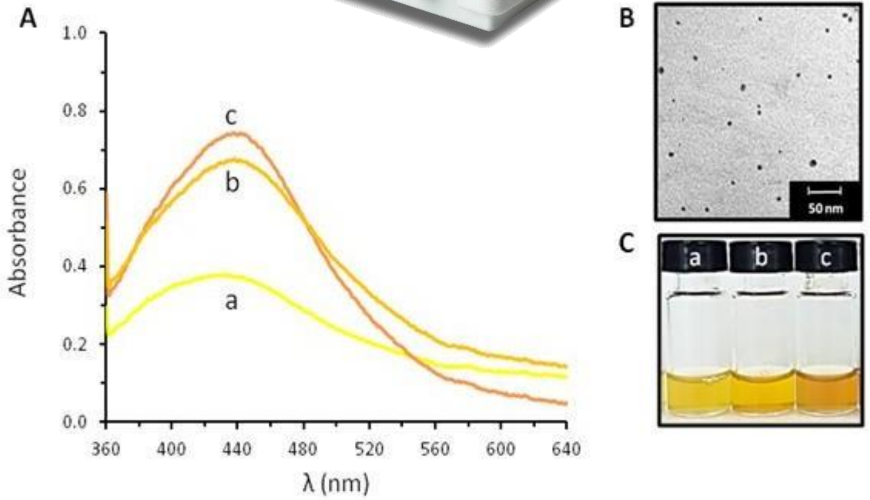


Metal nanoparticles formation

Reducing compounds evaluation trough Au and AgNPs formation



LSPR



Metal nanoparticles formation

Phenolic content and antioxidant capacity evaluation trough Au and AgNPs formation

sensors

MDPI

Review

Nanomaterial-Based Sensing and Biosensing of Phenolic Compounds and Related Antioxidant Capacity in Food

Flavio Della Pelle and Dario Compagnone *

… Nanomaterial-based method for estimating the antioxidant activity relies on the polyphenol-mediated growth of MNPs (AuNPs and AgNPs), and optical monitoring of the corresponding plasmon absorption bands…

SCAMPICCHIO, Matteo, et al. Nanoparticle-based assays of antioxidant activity. *Analytical chemistry*, 2006, 78.6: 2060-2063.

Table 11.1: Food antioxidants.

Antioxidant	Subclasses	Formula	Examples	Sources
Phenolic acids	Hydroxybenzoic acids	C_6–C_1	Gallic acid, *p*-hydroxybenzoic acid, protocatechuic acid, vanillic acid, syringic acid	Blackberry, raspberry, tea
	Hydroxycinnamic acids	C_6–C_3	Caffeic acid, ferulic acid, *p*-coumaric acid, sinapic acid	Blueberry, coffee
Flavonoids	Flavonols	C_6–C_3–C_6	Quercetin, kaempferol	Onions, leeks, broccoli
	Flavones		Apigenin, luteolin	Parsley, celery
	Flavanones		Naringenin, hesperetin, eriodictyol	Orange, grapefruit, lemon
	Flavanols		Catechin, epicatechin	Tea, chocolate
	Isoflavones		Genistein, daidzein, glycitein	Soy
	Anthocyanidins		Cyanidin, malvidin, delphinidin	Berries
Carotenoids	Xanthophylls	$C_{40}H_{56}O_n$	β-Cryptoxanthin, lutein, zeaxanthin, neoxanthin, violaxanthin, α-cryptoxanthin	Peppers, green leafy vegetables
	Carotenes	$C_{40}H_{56}$	α-Carotene, β-carotene, lycopene	Pumpkin, carrot, tomato
Vitamins	Vitamin C	$C_6H_8O_6$		Citrus fruits, kiwi, strawberry
	Vitamin E	$C_{29}H_{50}O_2$	Tocopherols, tocotrienols	Nuts, seeds, fish oil, whole grains

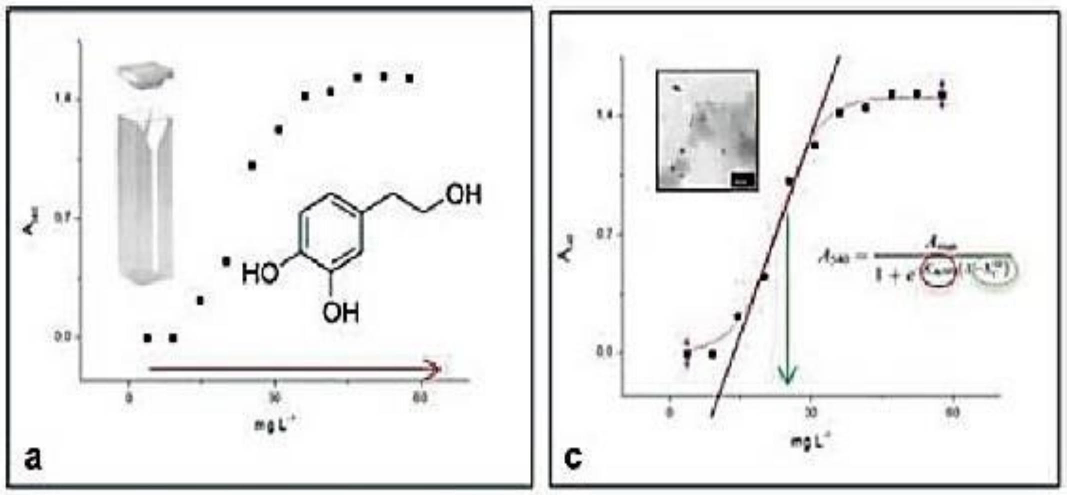
Polyphenols sensing

AuNPs

AoC
Idrophilic
Matrix Sample

- AoC evaluation
- The pH (8) avoid sugar interference
- High correlation with classical methods for antioxidant determination
- Sensitivity to intrinsic antioxidant power (o-diphenols most reactive)

Total assay time: 25 min



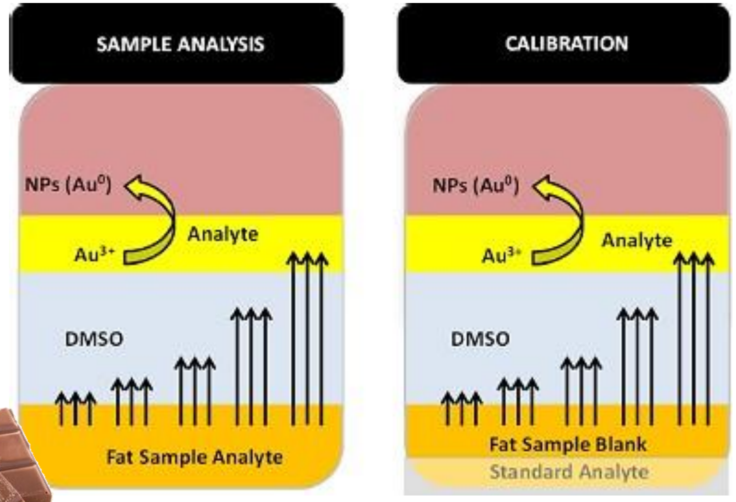
DELLA PELLE, Flavio, et al. Development of an Optical Sensing Strategy Based on Gold Nanoparticles Formation Driven by Polyphenols. Application to Food Samples. In: *Sensors*. Springer, Cham, 2015. p. 39-46.

AuNPs
Fat

AoC
Fat
Matrix Sample

- Total polyphenols determination (40C°)
- Extraction free: directly applicable in fat sample matrix
- Low amount of sample is required (30 µL)
- Rapid and robust
- Sensitive

Total assay time: 10 min

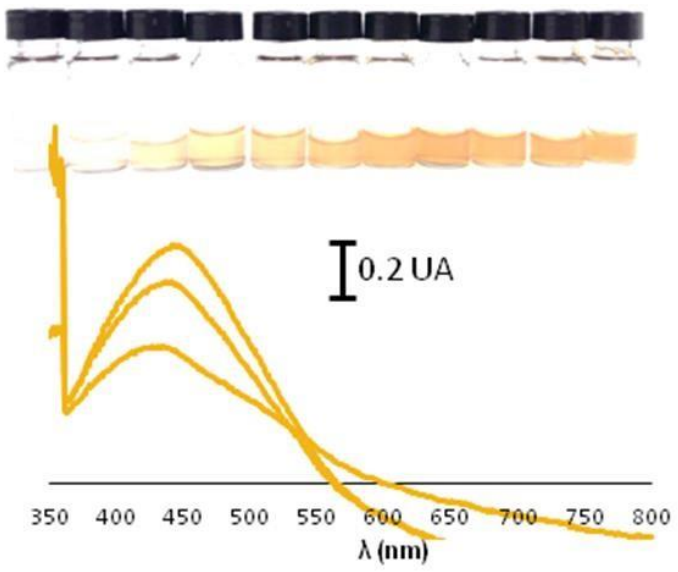


DELLA PELLE, Flavio, et al. Gold nanoparticles-based extraction-free colorimetric assay in organic media: an optical index for determination of total polyphenols in fat-rich samples. *Analytical chemistry*, 2015, 87.13: 6905-6911.

Metal nanoparticles formation

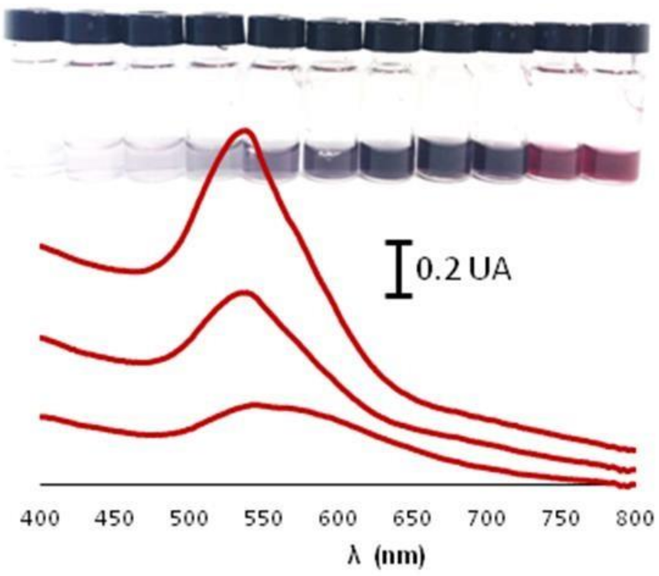
Phenolic content and antioxidant capacity evaluation trough Au and AgNPs formation

AgNPs

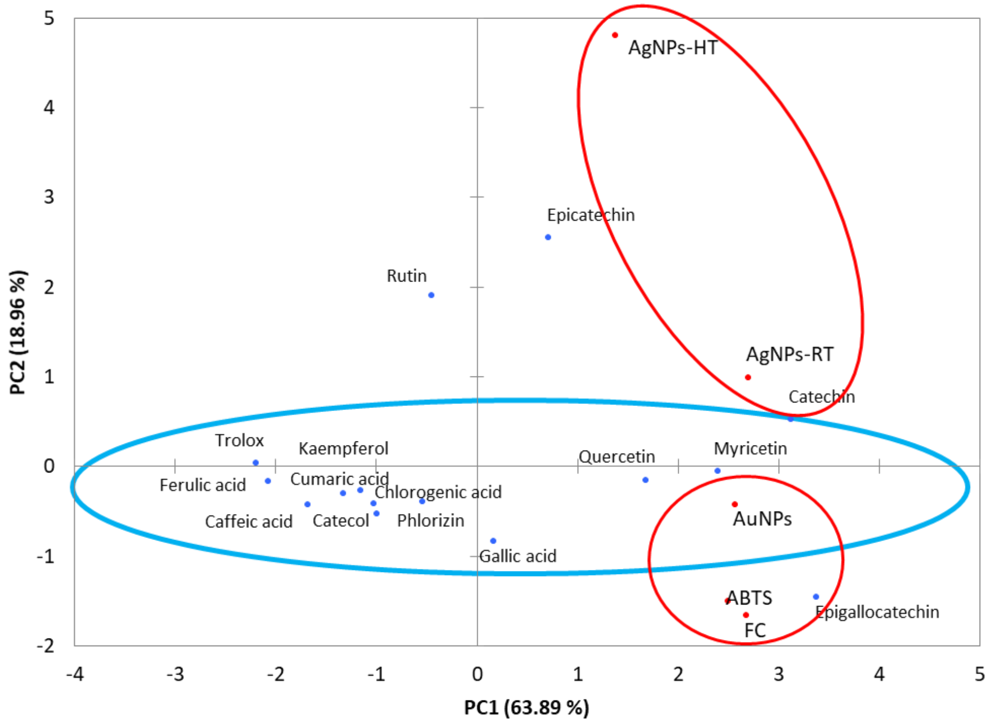


Epicatechin concentration:
2, 4 and 6 µM

AuNPs



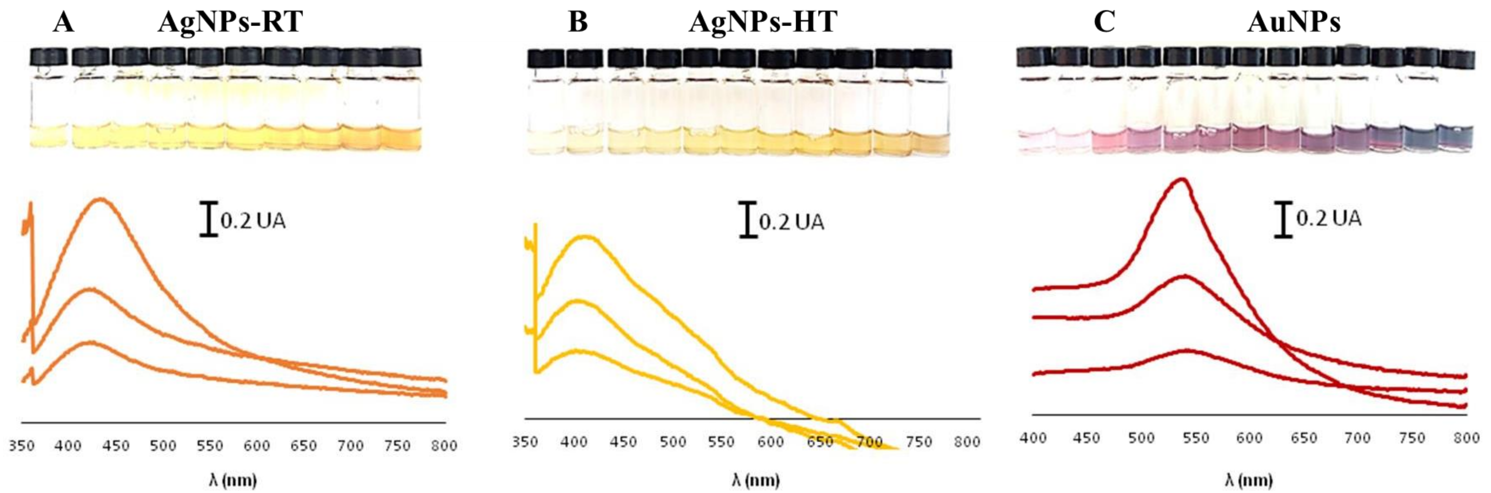
Epicatechin concentration:
70, 90, 110 µM



R	ABTS		FC		AgNPs-HT		AgNPs-RT		AuNPs	
ABTS	1	(p = 0)	0.876	(p = 0.002)	0.891	(p = 0.001)	0.956	(p = 0.000)	0.977	(p = 0.000)
FC	0.876	(p = 0.002)	1	(p = 0)	0.733	(p = 0.025)	0.913	(p = 0.001)	0.801	(p = 0.009)
AgNPs-HT	0.891	(p = 0.001)	0.733	(p = 0.025)	1	(p = 0)	0.770	(p = 0.015)	0.826	(p = 0.006)
AgNPs-RT	0.956	(p = < 0.0001)	0.913	(p = 0.001)	0.770	(p = 0.015)	1	(p = 0)	0.950	(p = < 0.0001)
AuNPs	0.977	(p = < 0.0001)	0.801	(P = 0.009)	0.826	(p = 0.006)	0.950	(p = < 0.0001)	1	(p = 0)

Metal nanoparticles formation

Phenolic content and antioxidant capacity evaluation in teas and infuses



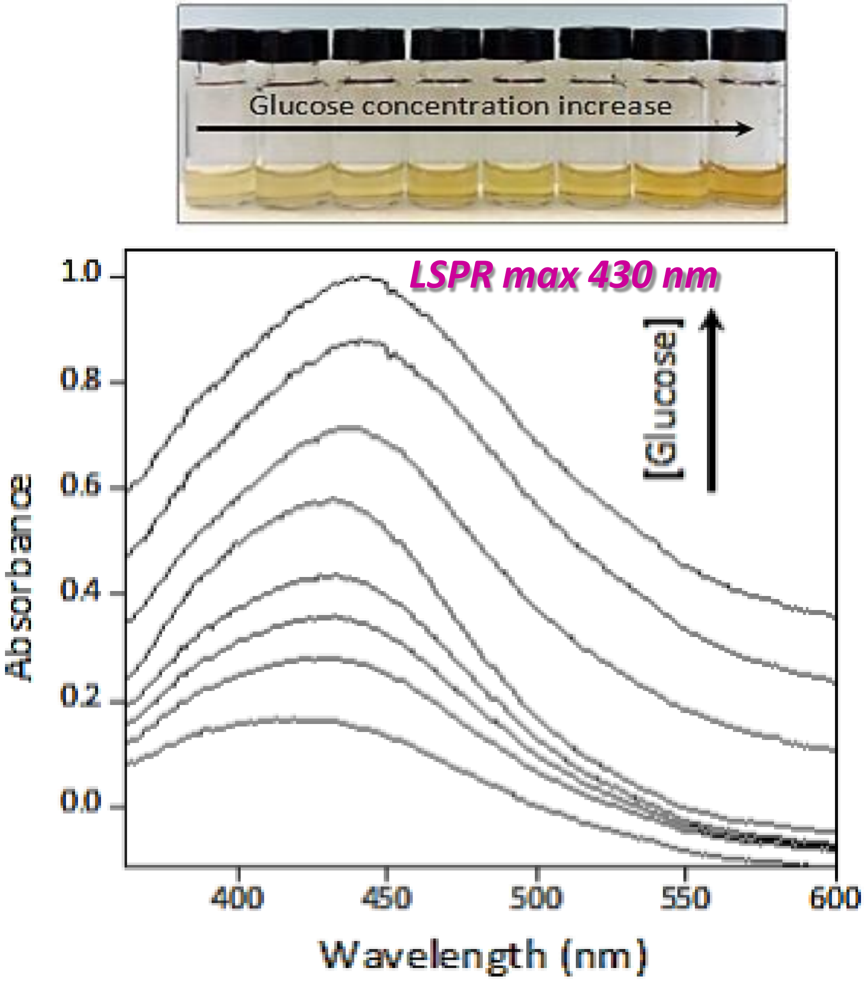
MNPs spectra obtained with AgNPs-*RT* (A), AgNPs-*HT* (B) and AuNPs (C) assays using increasing volume of the sample 'RE' ('relax')

VT: Vanilla Tea
TG: Green Tea
TC: Classic Tea
SD: sogni d'oro infused
RE: Relax infused
RB: Rosa di bosco Infused
LT: Lemon Tea
IN: Finocchio infused
DIG: Digestiva infused

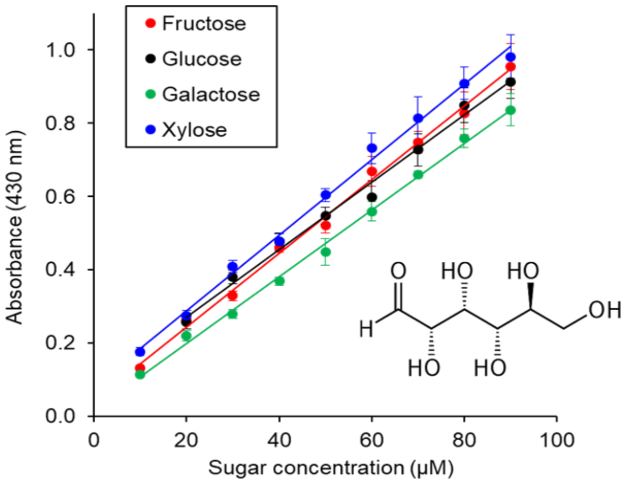
Sample / Method	DIG (g Kg^{-1})	RSD (%)	IN (g Kg^{-1})	RSD (%)	LT (g Kg^{-1})	RSD (%)	RB (g Kg^{-1})	RSD (%)	RE (g Kg^{-1})	RSD (%)	SD (g Kg^{-1})	RSD (%)	TC (g Kg^{-1})	RSD (%)	TG (g Kg^{-1})	RSD (%)	VT (g Kg^{-1})	RSD (%)
AgNPs-RT	8.66	4	1.20	9	9.91	5	5.31	3	9.12	8	9.62	7	49.50	8	143.01	3	52.19	4
AgNPs-HT	11.10	9	12.52	9	14.73	5			7.78	10	6.98	14	13.33	6	24.42	7	7.82	12
AuNPs	18.63	5	1.52	7	15.64	2	15.86	5	15.58	7	14.03	5	20.56	6	132.35	3	27.95	4
ABTS	3.03	12	1.12	14	11.26	7	0.70	14	2.13	9	2.21	12	11.55	8	54.57	5	8.92	7
FC	5.98	4	2.51	11	14.54	3	3.70	10	5.51	4	5.42	5	21.10	7	30.54	8	16.79	6

Metal nanoparticles formation

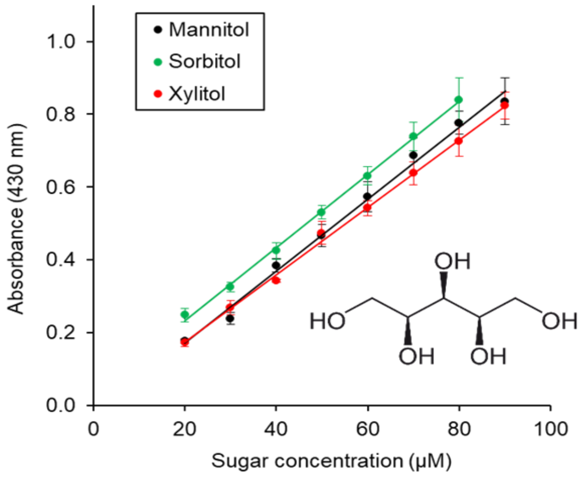
Sugars content evaluation trough AgNPs formation



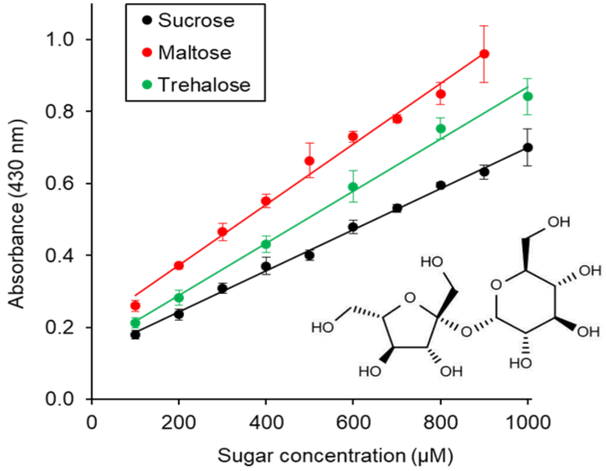
Monosaccharides



Polyols



Diosaccharides

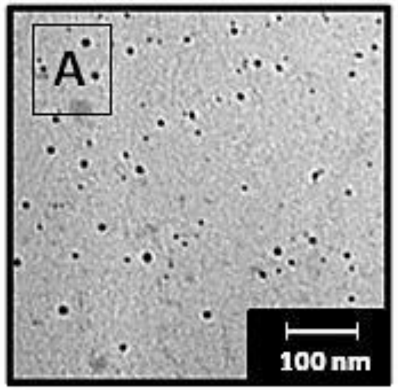


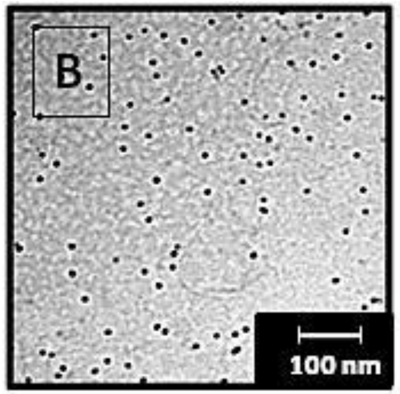
Metal nanoparticles formation

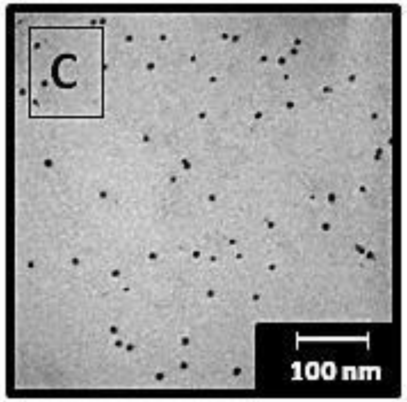
AgNPs Morphological study

Glucose | Sucrose | Xylitol

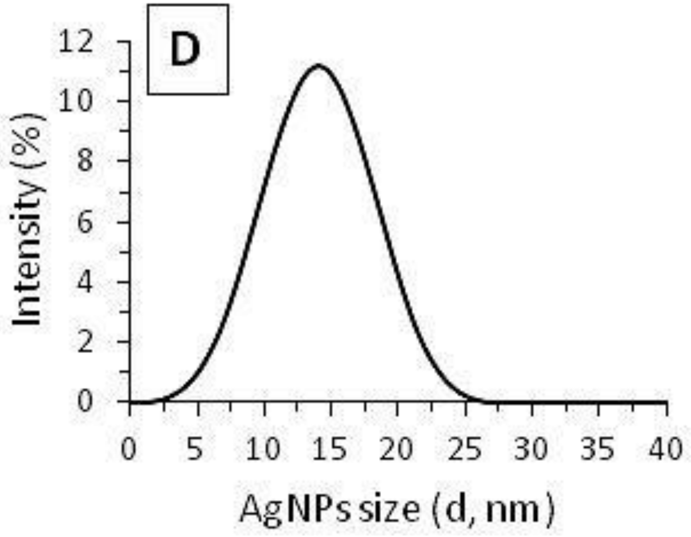
TEM

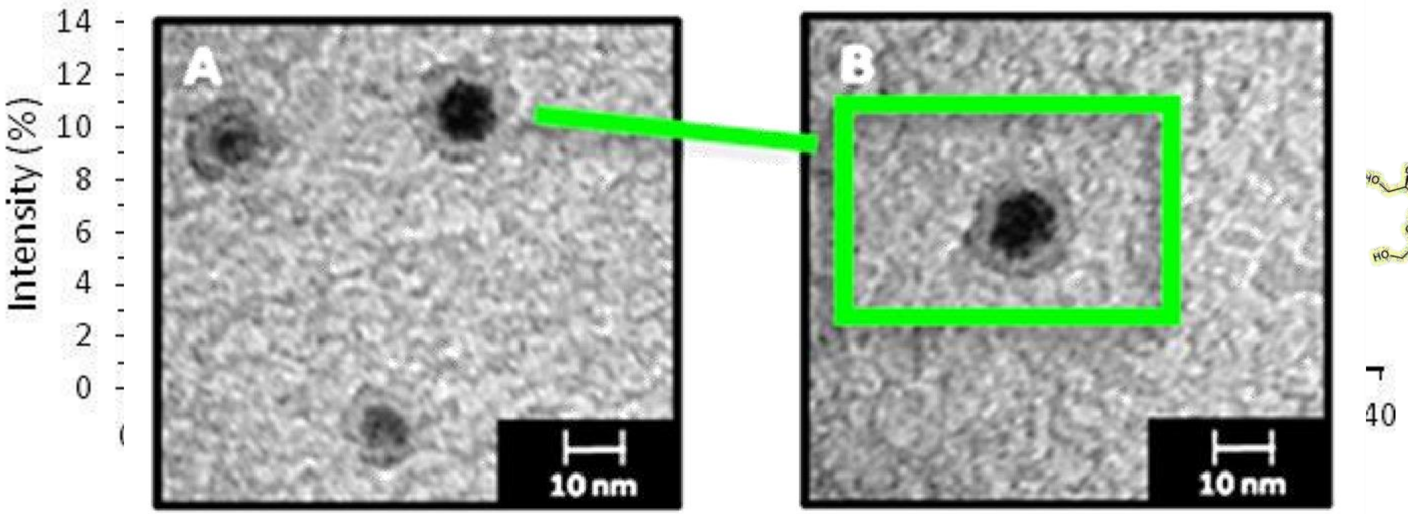


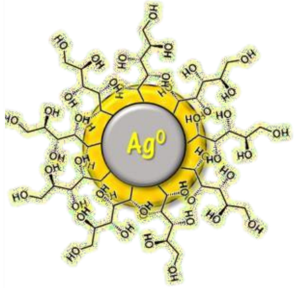




DLS







Determination of total sugars in real samples: AgNPs method vs. ion chromatography

Sample analysis

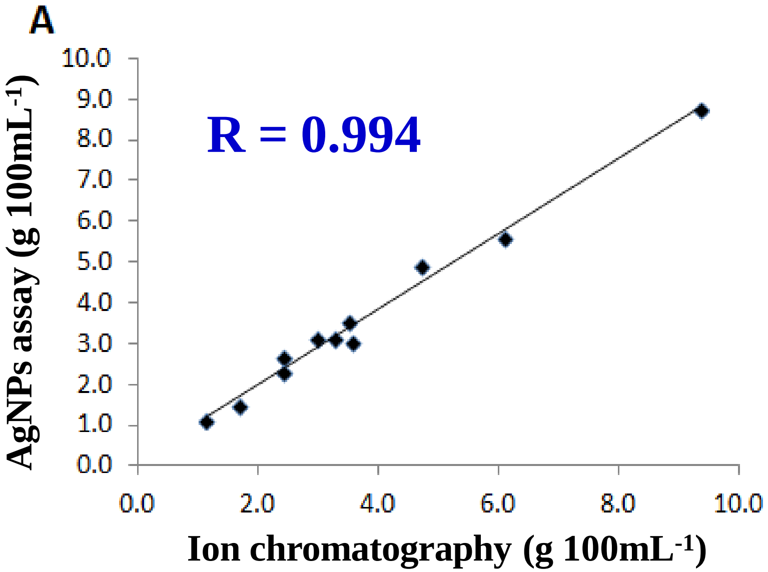
Samples challenged

- Soft drinks n° 6
- Apple extracts n° 6

Sample	AgNPs assay ($g\ 100\ mL^{-1}$, Glu. Eq.)	RSD (%, n = 5)	Ion chromatography ($g\ 100\ mL^{-1}$, Glu + Fru)	RSD (%, n = 3)	AgNPs assay relative error (%)
Peach tea	2.98 ± 0.14	4.74	3.13 ± 0.08	2.71	+ 5.0
Black tea	3.56 ± 0.23	6.51	3.05 ± 0.11	3.56	- 14.3
Coconut water	4.72 ± 0.13	2.84	4.93 ± 0.05	0.98	+ 4.4
Gaseous	3.50 ± 0.25	7.23	3.53 ± 0.04	1.21	+ 0.9
Cedrata	9.36 ± 0.27	2.85	8.74 ± 0.78	8.9	- 6.6
Tonic water	6.11 ± 0.07	1.15	5.62 ± 0.12	2.11	- 8.0
Apple 1	1.67 ± 0.02	1.12	1.50 ± 0.02	1.11	- 10.2
Apple 2	1.14 ± 0.04	3.41	1.14 ± 0.02	1.78	0.0
Apple 3	3.27 ± 0.04	1.30	3.12 ± 0.10	3.10	- 4.6
Apple 4	2.43 ± 0.23	9.42	2.67 ± 0.11	4.10	+ 9.9
Apple 5	2.43 ± 0.02	0.74	2.31 ± 0.9	3.80	- 5.0

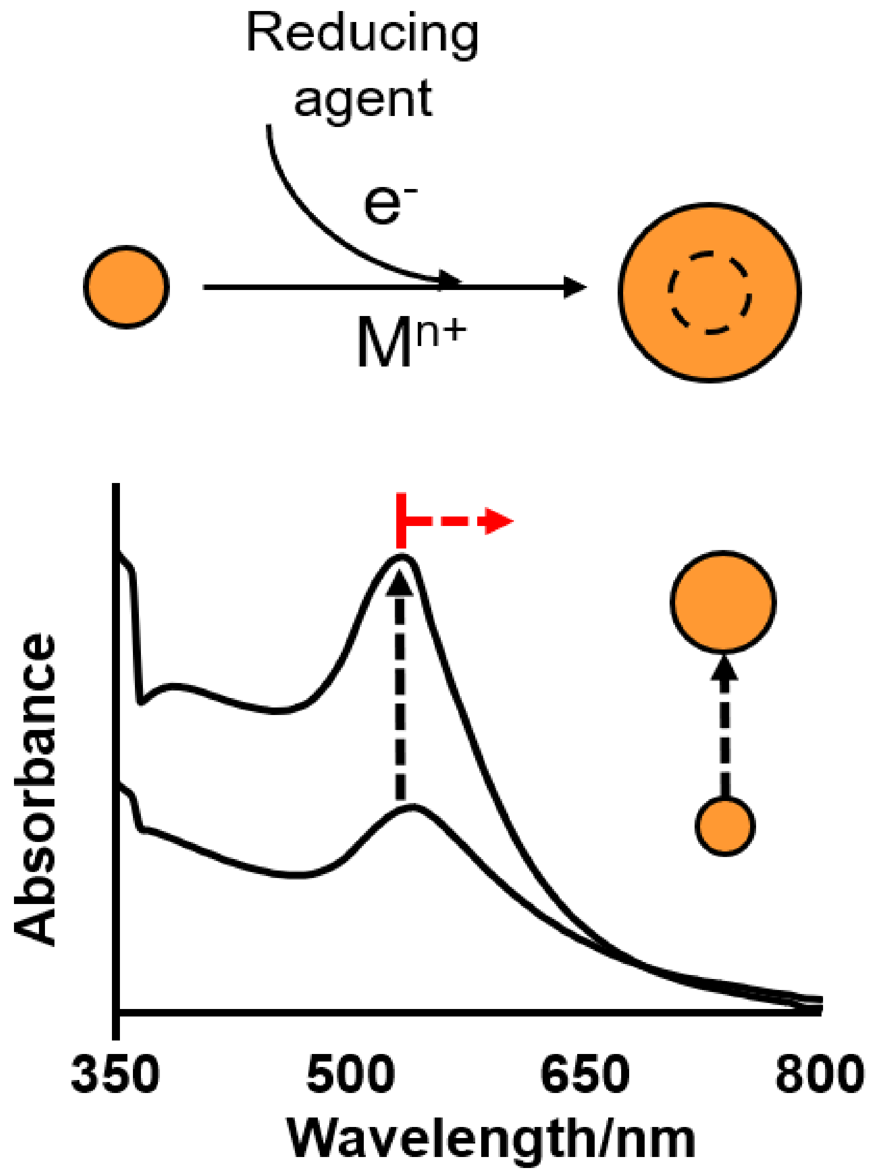
* mean value n= 3

Rel. error between -14.9 and + 9.9 %



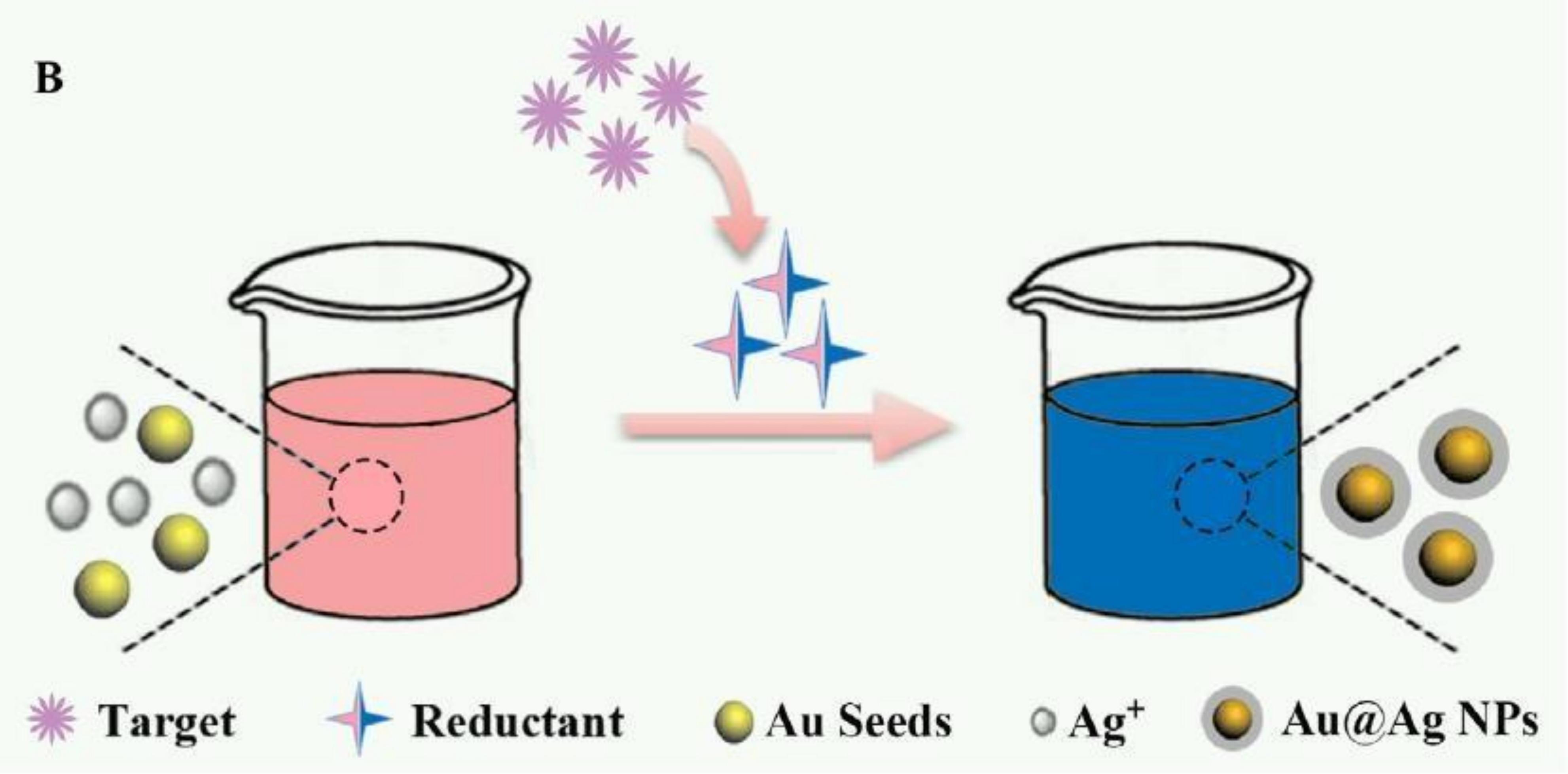
Recovery between 86 % and 118 %

Metal nanoparticle-based seed-growth strategies



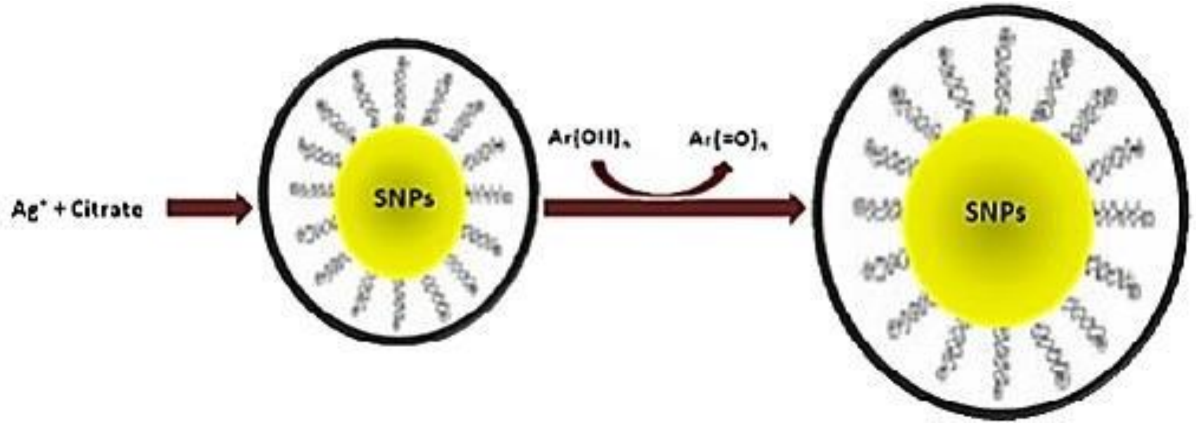
Metal nanoparticles growth

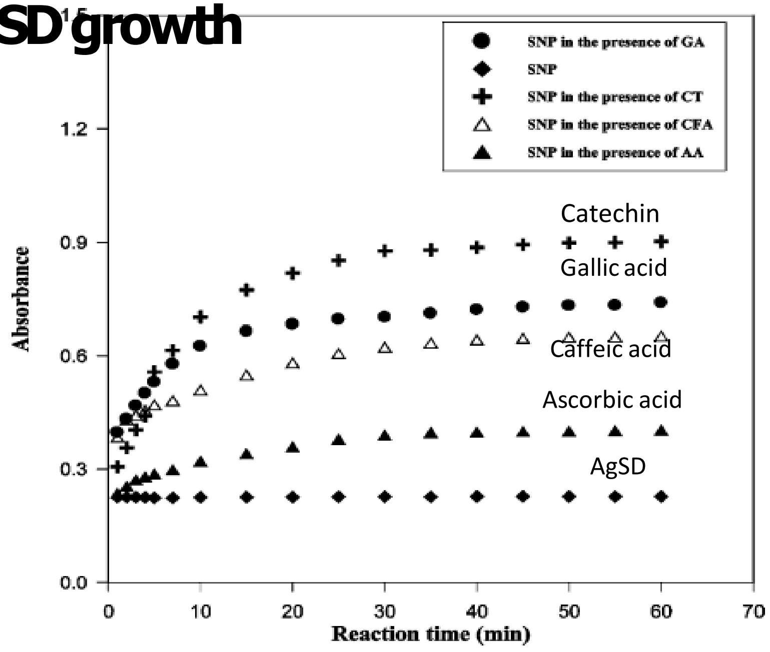
Main strategy

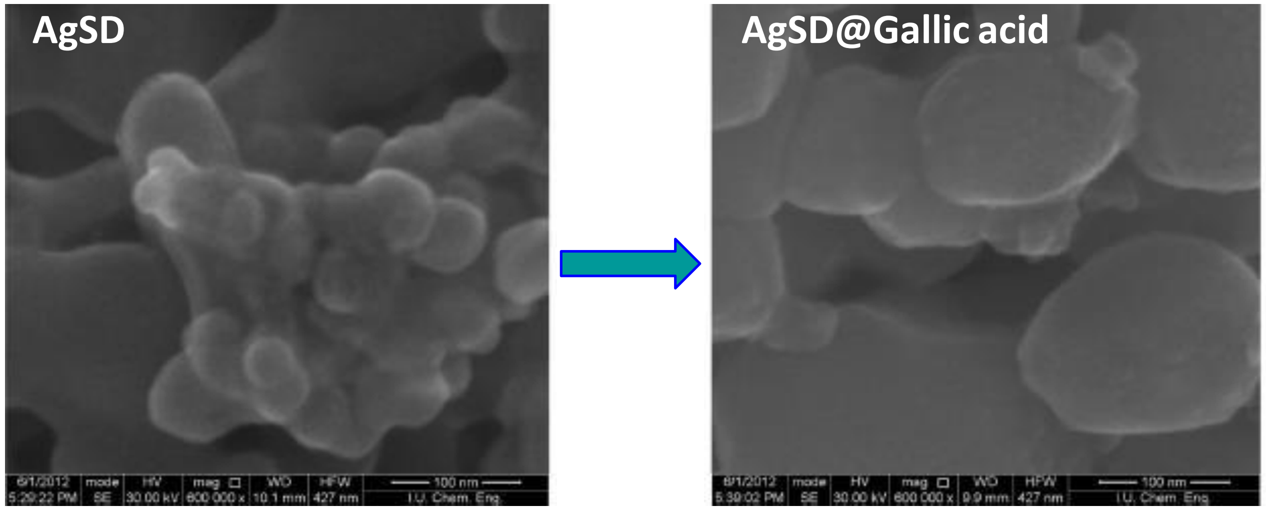


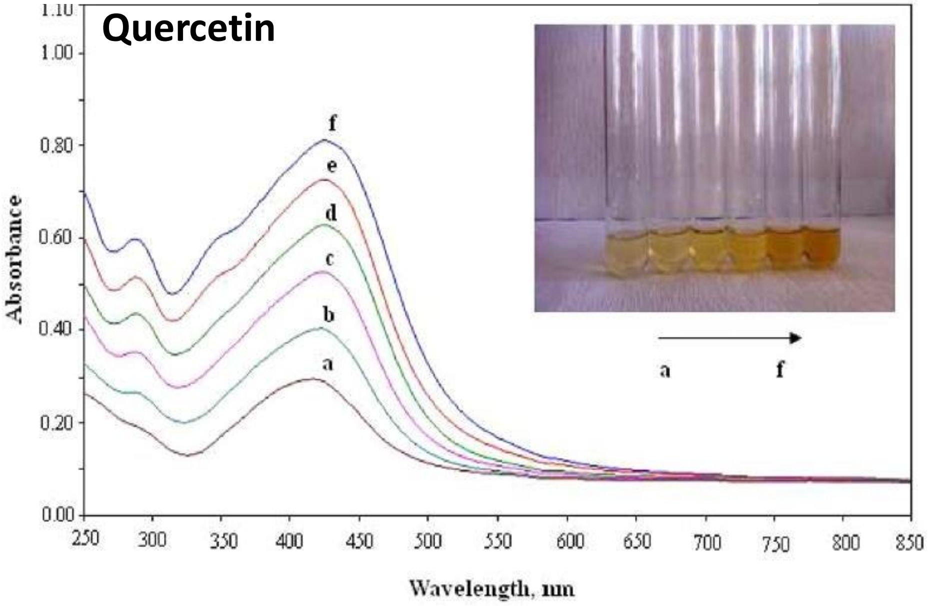
Metal nanoparticles growth

Phenolic content and antioxidant capacity evaluation trough AgSD growth









analytical chemistry

Article

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Development of a Silver Nanoparticle-Based Method for the Antioxidant Capacity Measurement of Polyphenols

Mustafa Özyürek, Nilay Güngör, Sefa Baki, Kubilay Güçlü, and Reşat Apak*

Metal nanoparticles growth

Phenolic content and antioxidant capacity evaluation via AgSD growth
Standards evaluation ad sample analysis

Table 1. Linear Equations, Correlation Coefficients (r), TEAC Coefficients,[a] and Linear Ranges for Antioxidants, with Respect to the Proposed SNPAC Method

antioxidants	linear equation and correlation coefficients	linear range (μM)	$TEAC_{SNPAC}$	$TEAC_{CUPRAC}$[b]
Simple Phenolic Acids				
gallic acid	$A = 2.27 \times 10^4 c + 0.01$ ($r = 0.9991$)	1.67−52.30	2.91	2.62
Hydroxycinnamic Acids				
rosmarinic acid	$A = 3.90 \times 10^4 c + 0.01$ ($r = 0.9977$)	1.02−30.51	5.02	5.30
caffeic acid	$A = 1.93 \times 10^4 c + 0.02$ ($r = 0.9990$)	1.55−61.14	2.47	2.80
chlorogenic acid	$A = 2.37 \times 10^4 c + 0.02$ ($r = 0.9981$)	1.26−49.79	3.04	2.47
Flavonols				
quercetin	$A = 2.99 \times 10^4 c + 0.01$ ($r = 0.9995$)	1.33−39.80	3.83	4.38
fisetin	$A = 2.82 \times 10^4 c - 0.019$ ($r = 0.9978$)	2.44−43.20	3.62	3.90
Flavan-3-ols				
ECG	$A = 4.16 \times 10^4 c + 0.02$ ($r = 0.9993$)	0.72−28.36	5.33	5.30
EGCG	$A = 3.31 \times 10^4 c + 0.02$ ($r = 0.9994$)	0.91−35.65	4.24	4.88
EC	$A = 2.70 \times 10^4 c + 0.03$ ($r = 0.9988$)	0.74−43.33	3.46	2.77
catechin	$A = 2.82 \times 10^4 c + 0.04$ ($r = 0.9941$)	0.35−41.13	3.61	3.09
EGC	$A = 2.84 \times 10^4 c - 0.01$ ($r = 0.9994$)	2.11−42.60	3.64	3.34
Flavons				
luteolin	$A = 2.08 \times 10^4 c + 0.03$ ($r = 0.9952$)	0.96−56.25	2.66	2.38
rutin	$A = 2.84 \times 10^4 c + 0.03$ ($r = 0.9974$)	0.70−41.20	3.64	2.56
apigenin	$A = 1.92 \times 10^4 c + 0.01$ ($r = 0.9973$)	2.19−62.10	2.47	0.12
Others				
ascorbic acid	$A = 1.13 \times 10^4 c + 0.04$ ($r = 0.9995$)	0.88−103.00	1.44	0.96
α-tocopherol	$A = 1.04 \times 10^4 c + 0.04$ ($r = 0.9963$)	0.96−111.00	1.33	1.10

[a]TEAC coefficients (significantly different) (by exclusion of the values for apigenin with highest TEAC variability; $P = 0.05$, $F_{exp} = 1.487$, $F_{crit\ (table)} = 4.600$, $F_{exp} < F_{crit\ (table)}$). [b]Data taken from refs 2 and 20. $TEAC_{CUPRAC} = 1.16\ TEAC_{SNPAC} - 0.782$ ($r = 0.936$).

Recovery study

Table 2. Precision and Recovery of the Proposed SNPAC Method

added conc (μM)	mean (μM)	stand dev, SD	rel stand dev, RSD (%)	REC (%)[a]
RT Addition to Green Tea				
5.43	5.15 ± 0.09	0.04	0.78	94.8
10.86	10.42 ± 0.17	0.07	0.67	96.0
21.72	21.16 ± 0.20	0.08	0.38	97.4
CT Addition to Green Tea				
3.66	3.48 ± 0.22	0.09	2.61	95.1
7.32	7.52 ± 0.19	0.08	1.06	102.7
14.64	14.82 ± 0.20	0.08	0.54	101.2
GA Addition to Green Tea				
4.65	4.67 ± 0.22	0.09	1.93	100.2
9.30	9.14 ± 0.10	0.04	0.44	98.3
18.6	18.18 ± 0.17	0.07	0.36	97.7
CT Addition to Olive Oil				
3.66	3.38 ± 0.16	0.06	1.87	92.3
7.32	6.91 ± 0.12	0.05	0.72	94.4
14.64	14.07 ± 0.10	0.04	0.28	96.1

[a]Recovery ($N = 3$).

Methods reliability

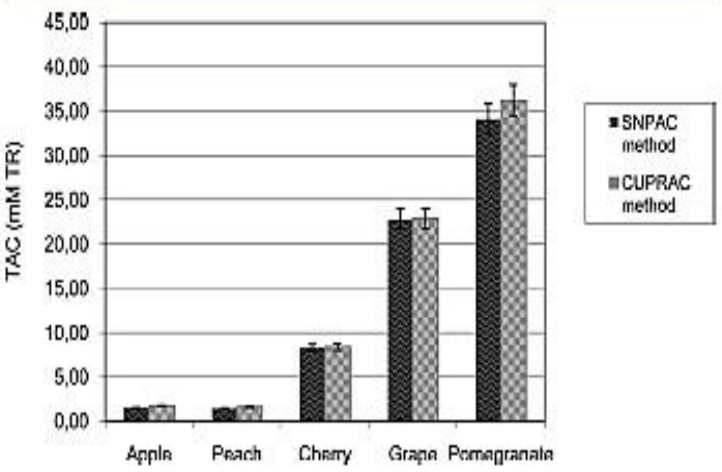
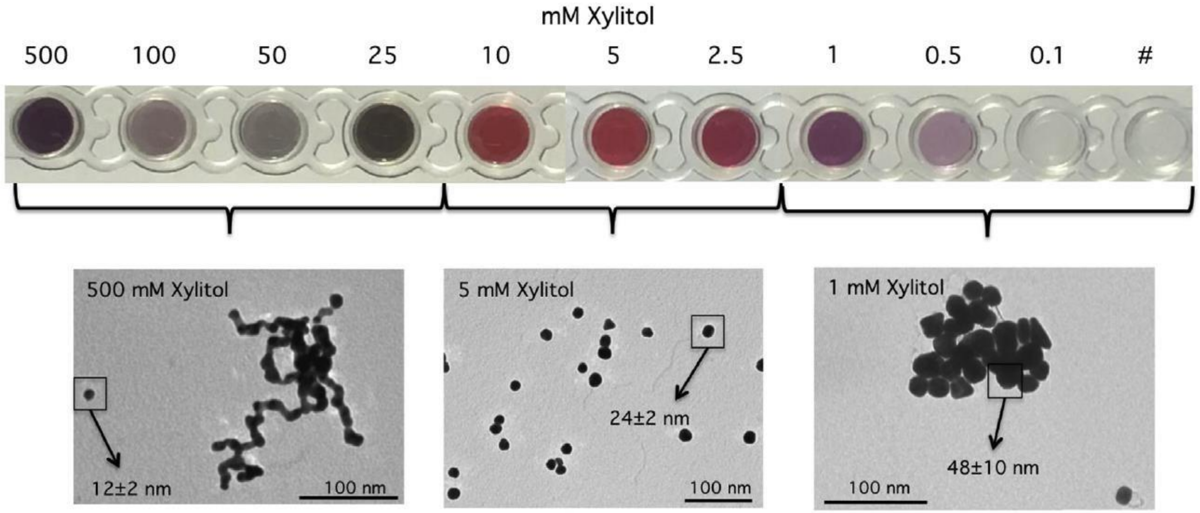


Figure 5. Comparative TAC values (mM TR equiv) of some commercial fruit juices measured by the SNPAC and CUPRAC assays. Data are presented as (mean ± SD) (error bars), $N = 3$. ($P = 0.05$, $F_{exp} = 0.775$, $F_{crit\ (table)} = 7.709$, $F_{exp} < F_{crit\ (table)}$.)

Metal nanoparticles growth

Xylitol monitoring trough AuNPs growth

Seed formation and growth phenomena study



Analytica Chimica Acta xxx (2017) 1–8

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Analytica Chimica Acta

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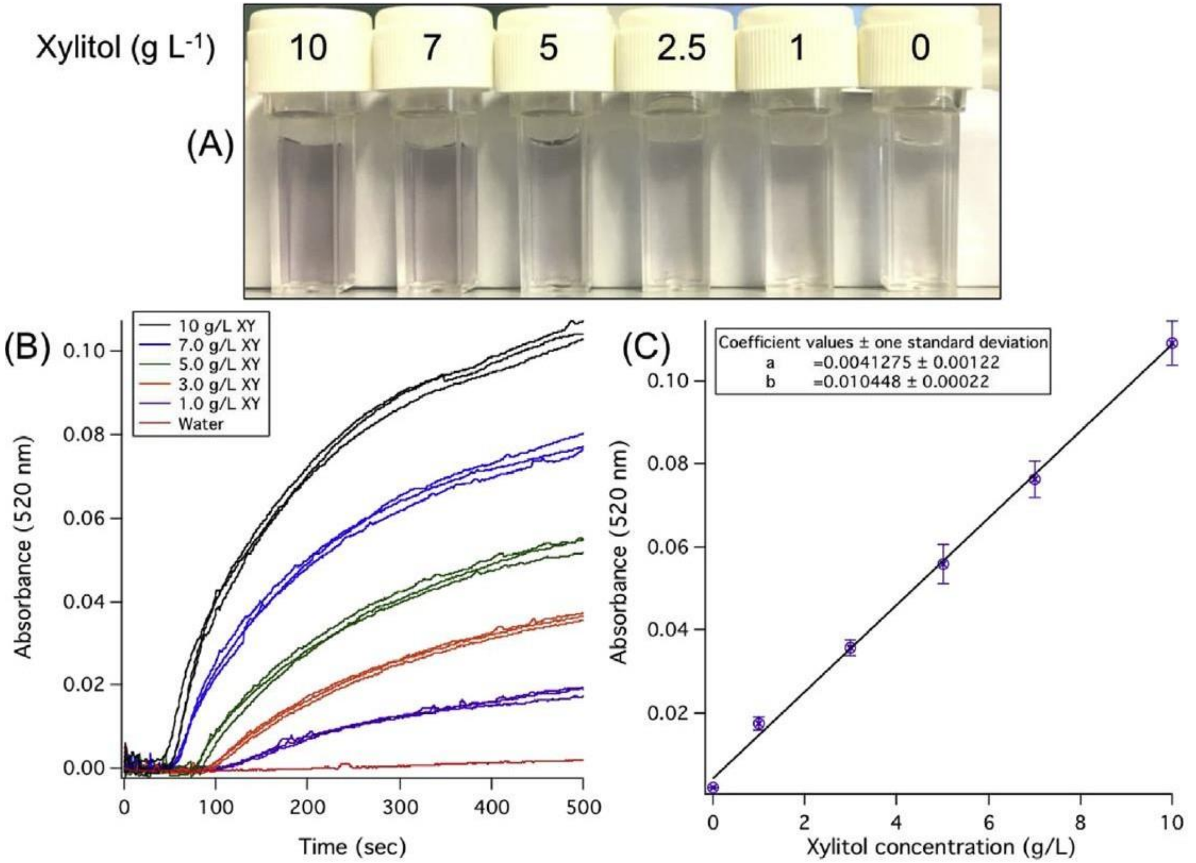
The early nucleation stage of gold nanoparticles formation in solution as powerful tool for the colorimetric determination of reducing agents: The case of xylitol and total polyols in oral fluid

S. Scarano*, E. Pascale, M. Minunni

Dose-response kinetic and curve



Metal nanoparticles growth

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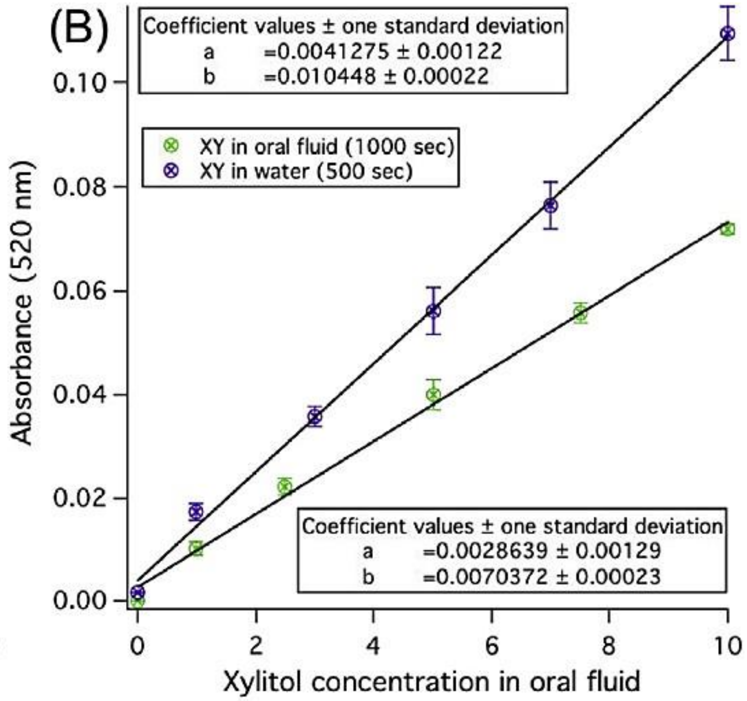
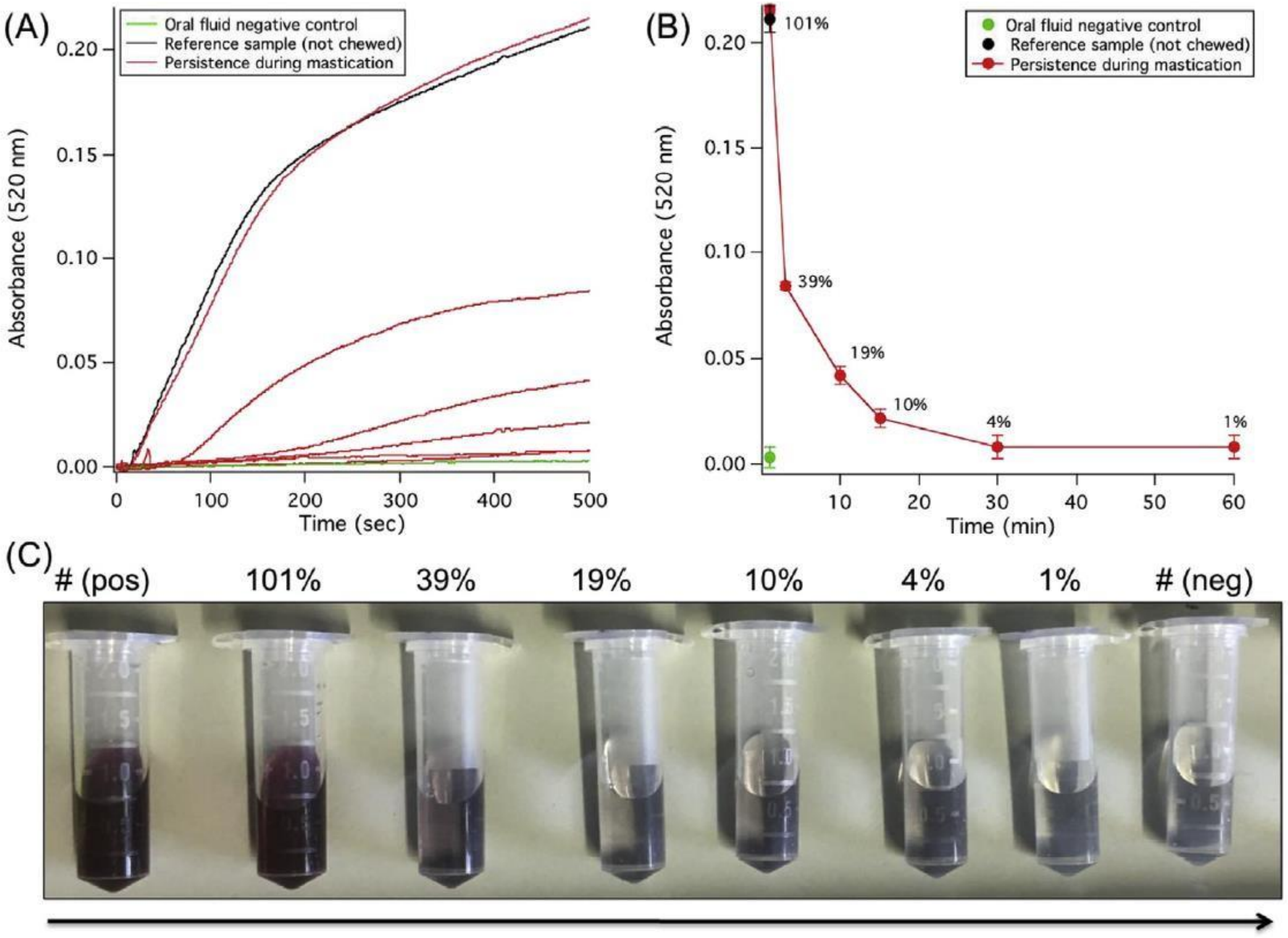
Xylitol monitoring in human saliva trough AuNPs growth

Recovery study

Methods evaluation for sample analysis

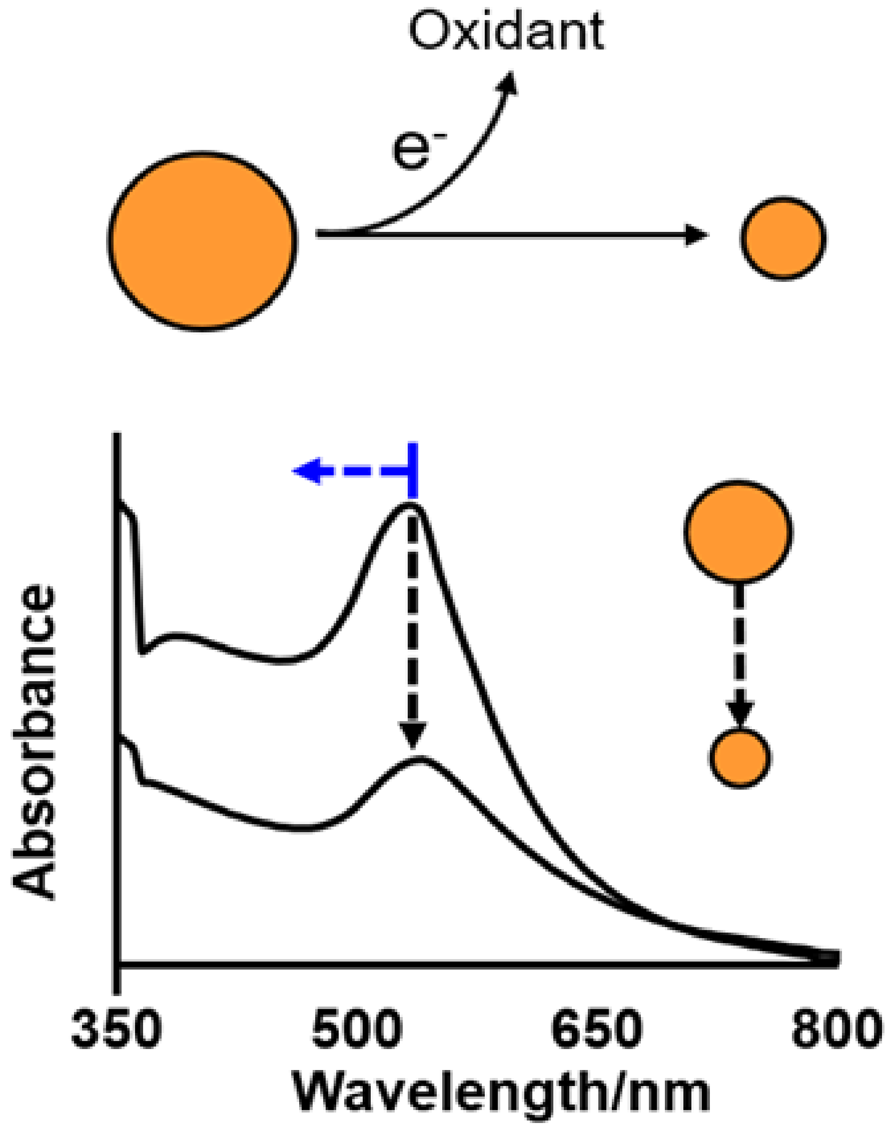


Xylitol monitoring 1 h of chewing-gum



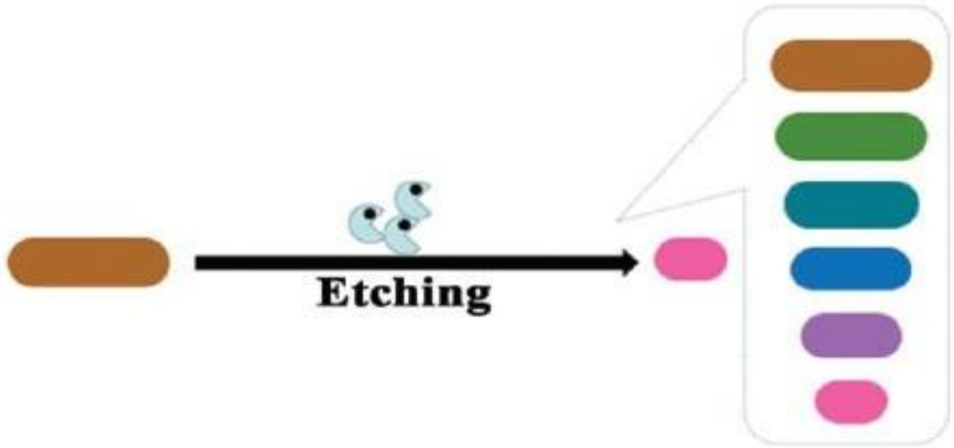
Xylitol decay Time (min)

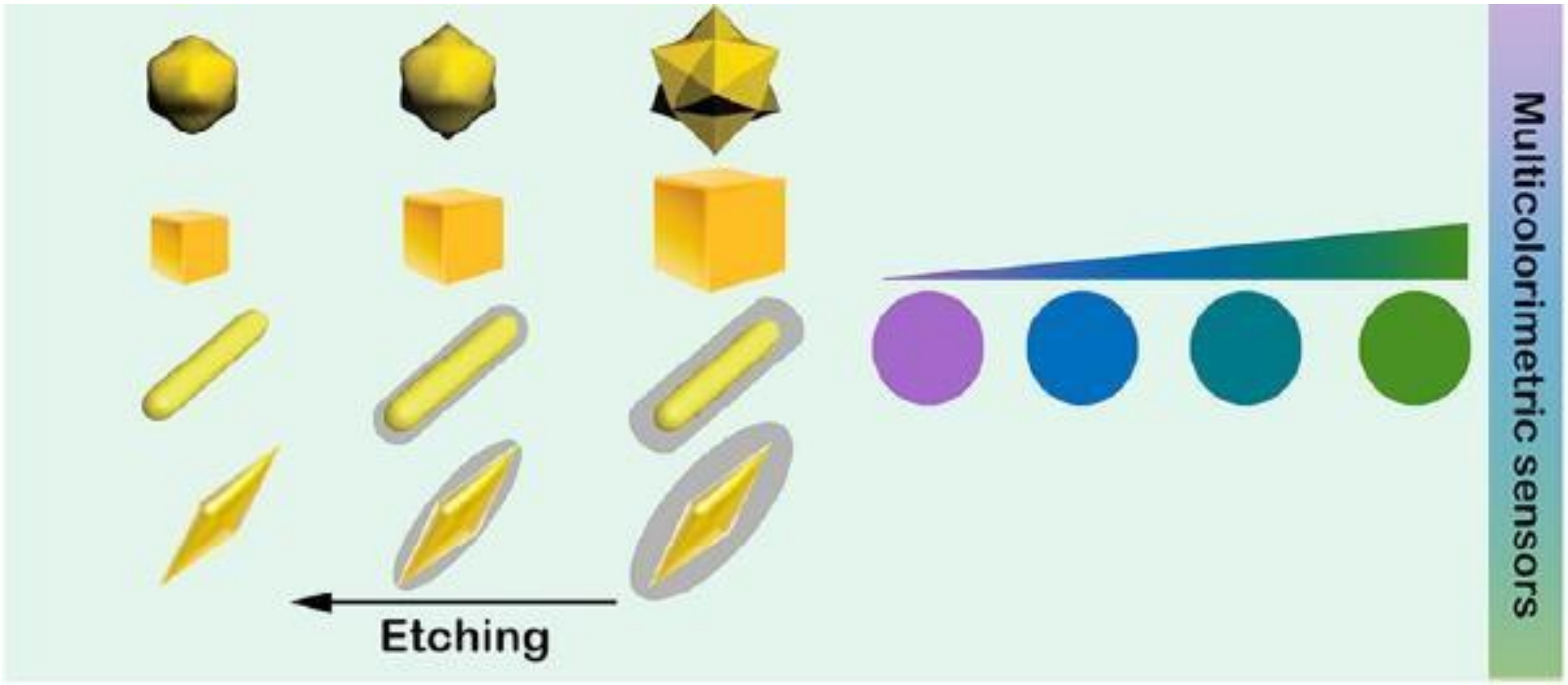
Metal nanoparticle etching



Metal nanoparticles etching

Main strategy

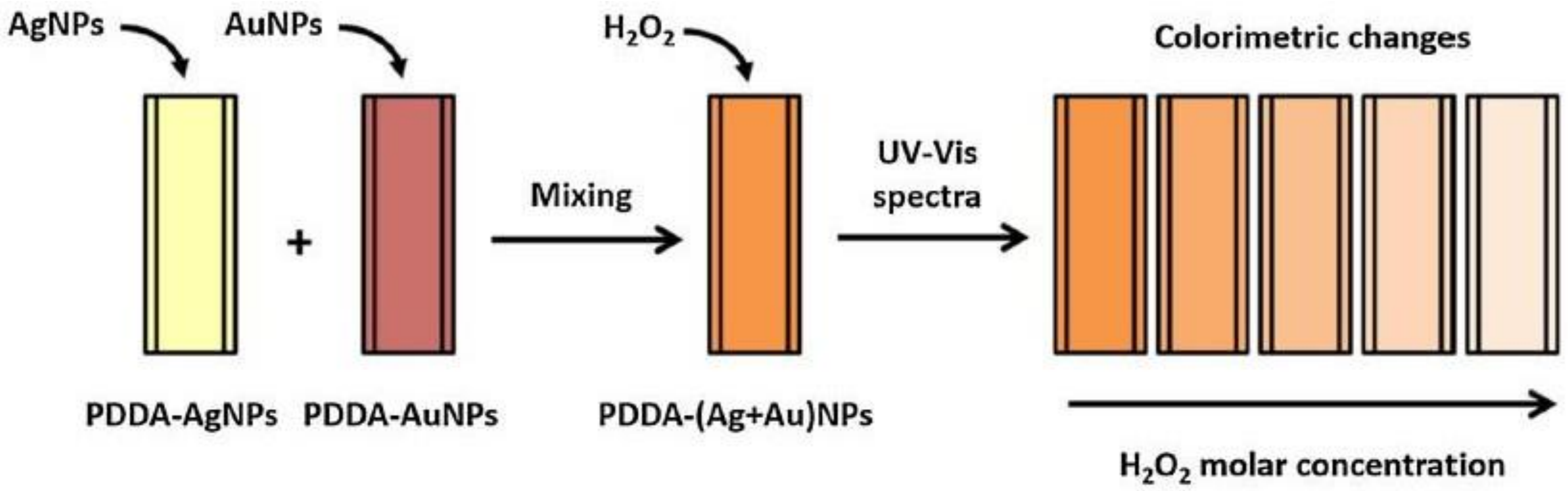


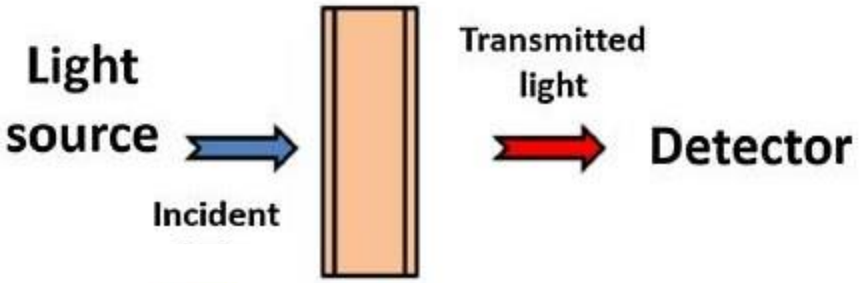


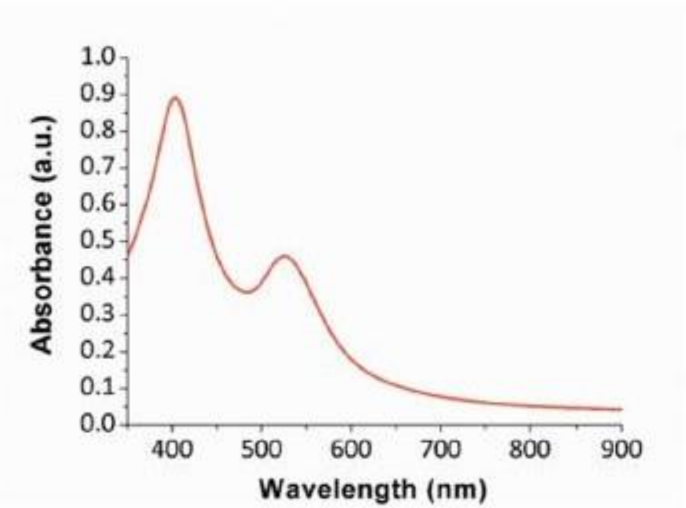
Metal nanoparticles etching

H_2O_2 determination trough MNPs etching

PDDA- Poly(diallyldimethylammoniumchloride)







Sensors and Actuators B 251 (2017) 624–631
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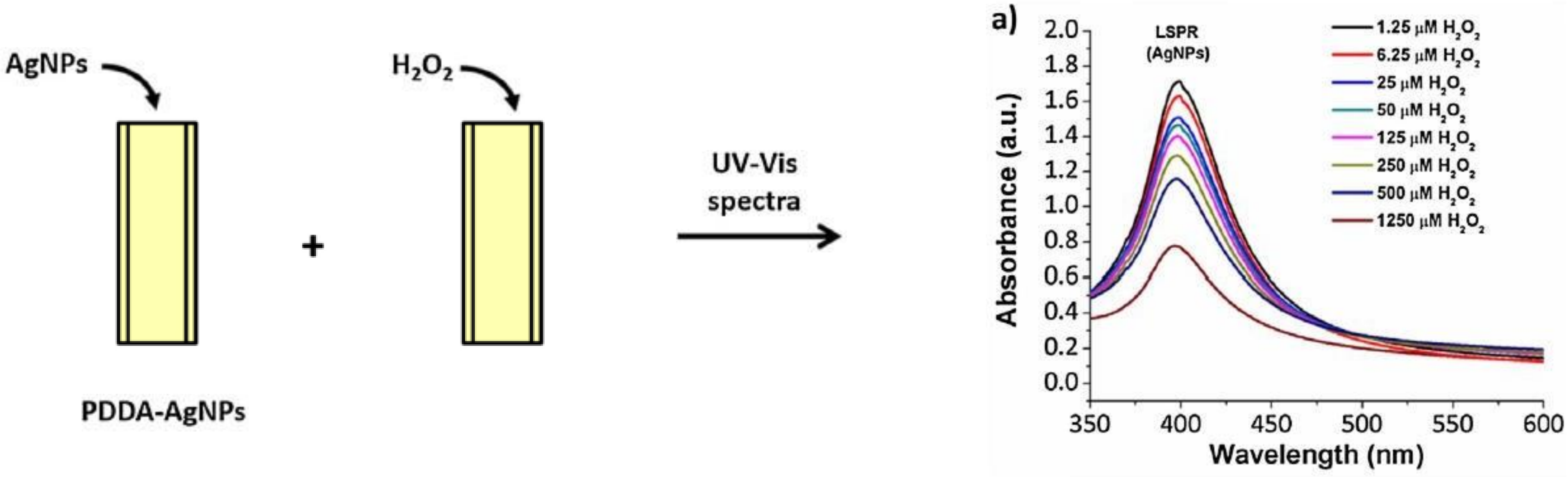
journal homepage: www.elsevier.com/locate/snb

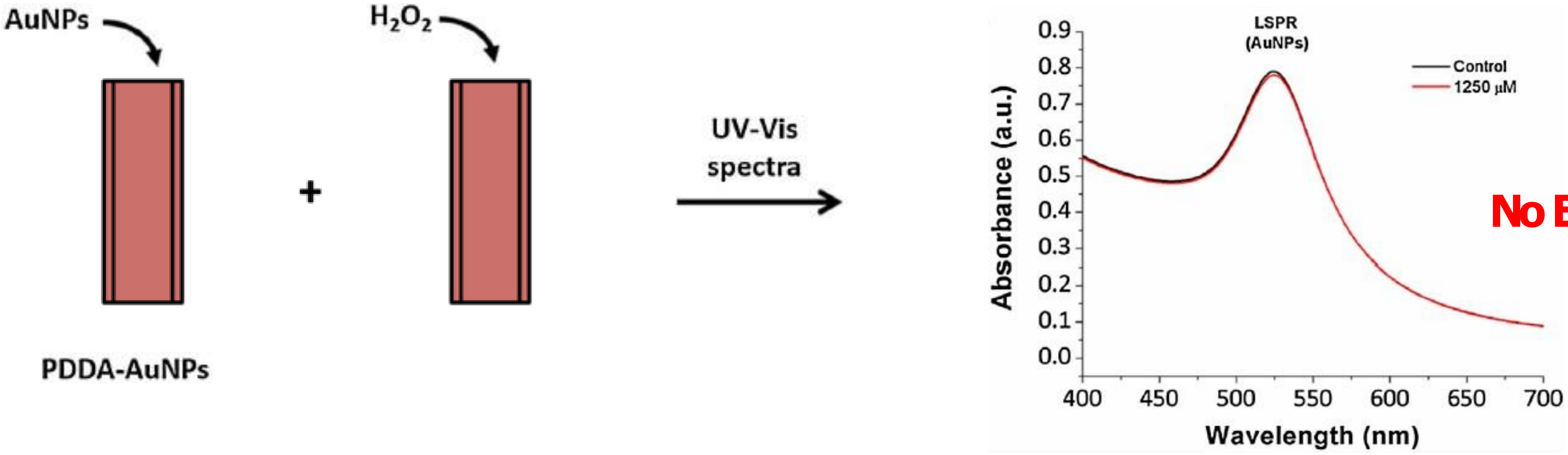
A self-referenced optical colorimetric sensor based on silver and gold nanoparticles for quantitative determination of hydrogen peroxide

Pedro J. Rivero[a,*], Elia Ibañez[b], Javier Goicoechea[b], Aitor Urrutia[b], Ignacio R. Matias[c], Francisco J. Arregui[b]

Metal nanoparticles etching

Etching phenomena study

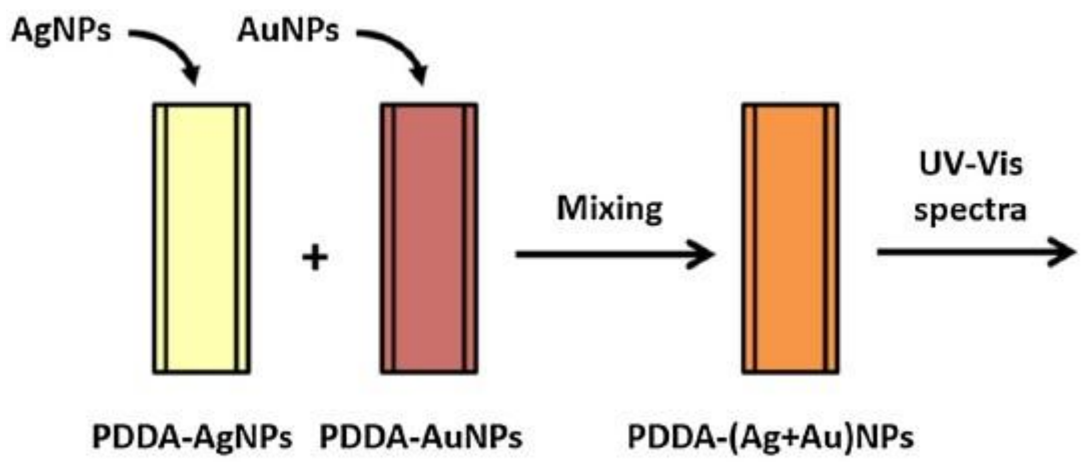


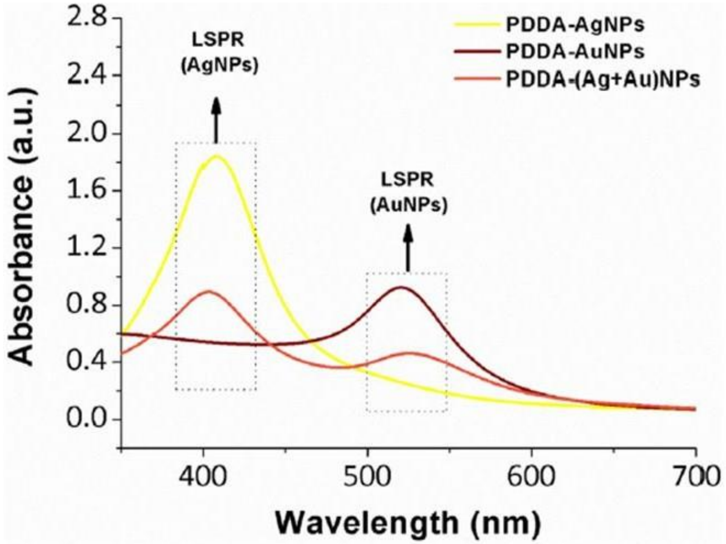


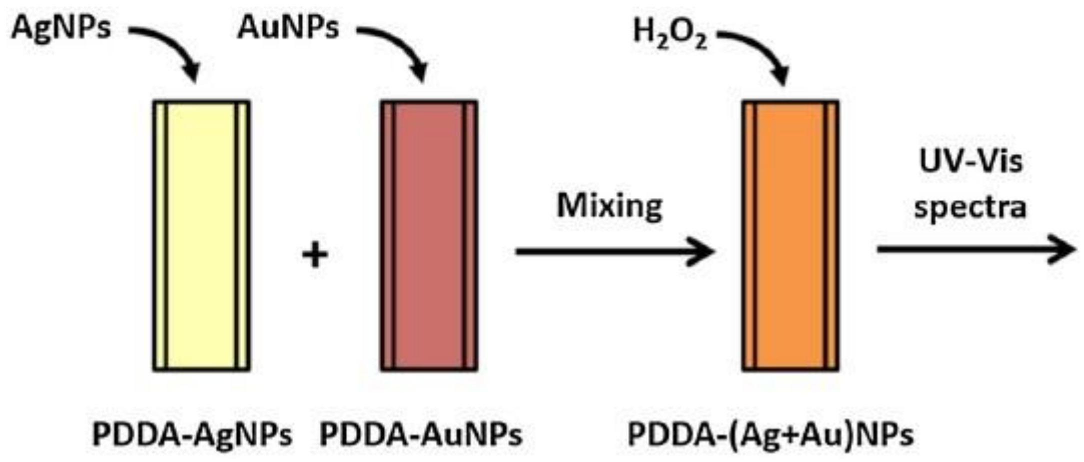
No Etching phenomena

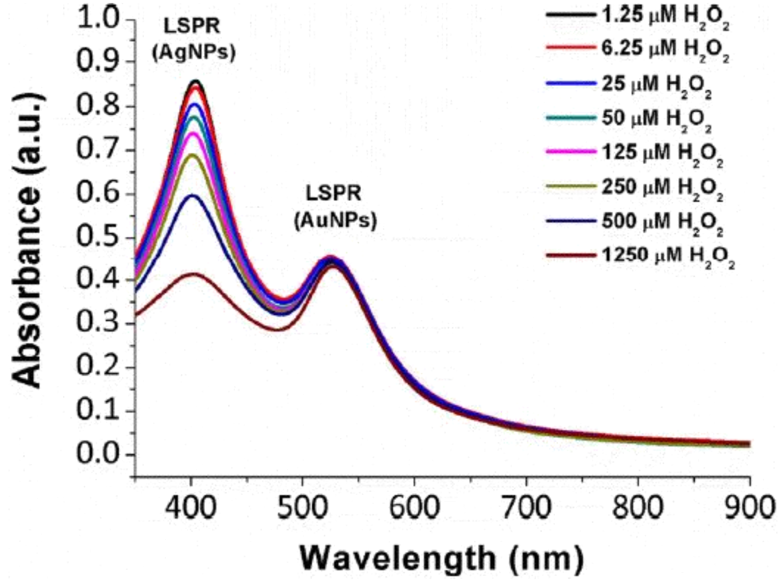
Metal nanoparticles etching

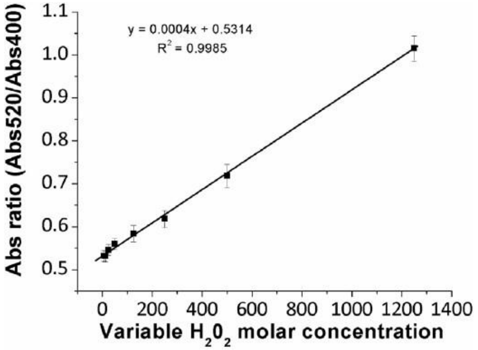
Etching phenomena study. H_2O_2 determination

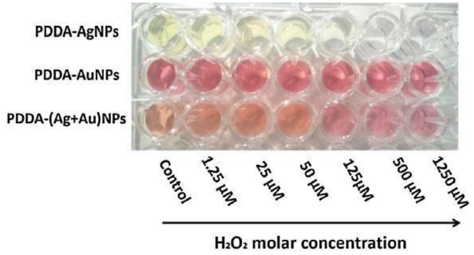










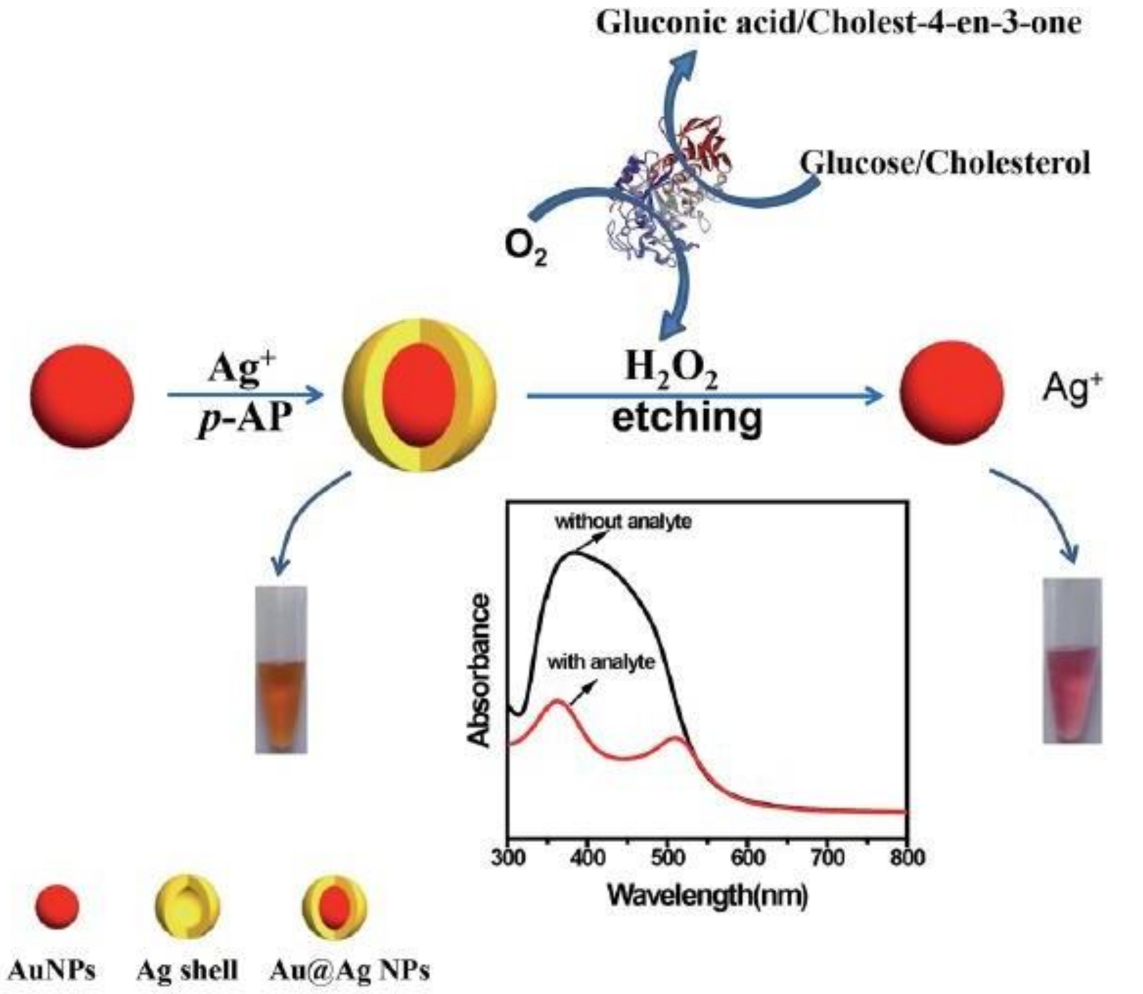


Metal nanoparticles etching

Glucose and cholesterol evaluation trough MNPs etching

$$\text{Glucose} + O_2 + H_2O \xrightarrow{\text{GOx}} \text{gluconic acid} + H_2O_2$$

$$\text{Cholesterol} + O_2 + H_2O \xrightarrow{\text{ChOx}} \text{cholest-4-en-3-one} + H_2O_2$$



Scheme 1 Schematic illustration of the formation of Au@Ag NPs and its application for the colorimetric detection of H_2O_2 and glucose/cholesterol.

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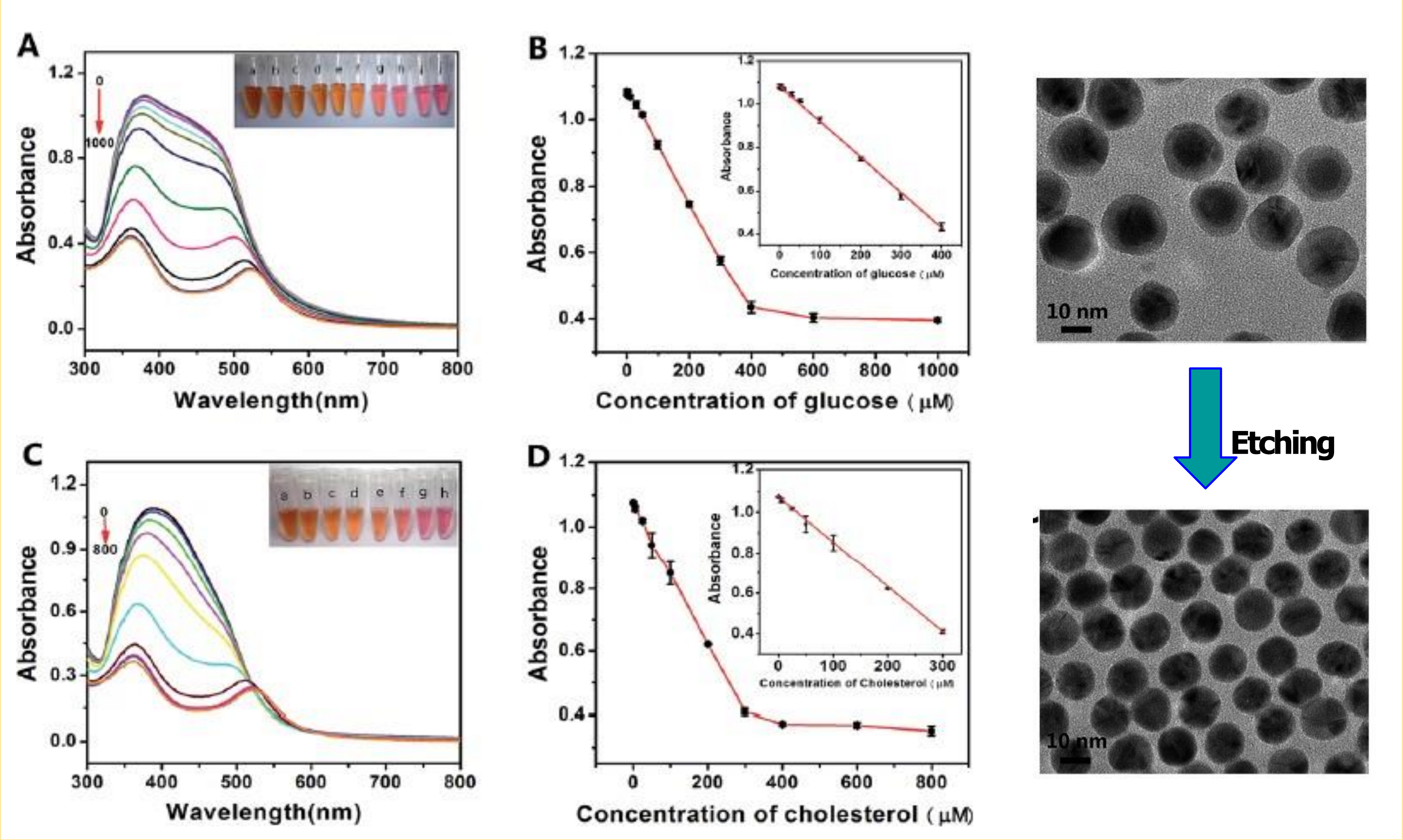
Sensitive colorimetric detection of glucose and cholesterol by using Au@Ag core–shell nanoparticles†

Xuehong Zhang,[a] Min Wei,[b] Bingjing Lv,[a] Yuanjian Liu,[a] Xu Liu[a] and Wei Wei*[a]

Metal nanoparticles etching

Glucose and cholesterol detrmination trough MNPs etching

Dose-response curve



Recovery study

Table 1 Recovery measurements of glucose in human urine samples and free cholesterol in human serum samples

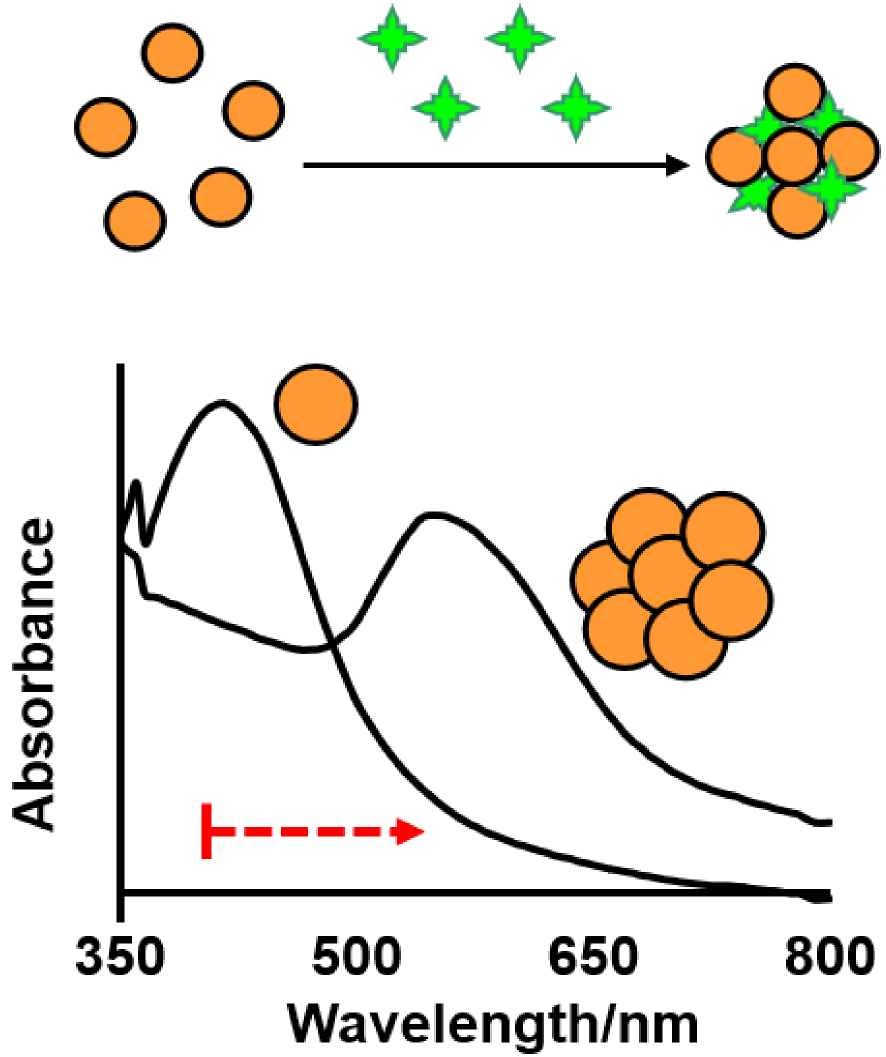
Analytes	Spiked (mM)	Found (mM)	Recovery (%)	RSD (%) ($n = 3$)
Glucose	0	0.580	—	0.84
	1	1.552	97.2	0.51
	5	5.530	99.0	1.02
	10	11.041	104.6	2.66
	30	31.037	101.5	3.83
Cholesterol	0	1.544	—	0.90
	1	2.610	106.6	0.43
	5	6.320	95.6	2.69
	10	11.715	101.7	1.88
	30	31.283	99.1	5.88

Sample analysis

Table 2 Determination of glucose concentration in human serum samples

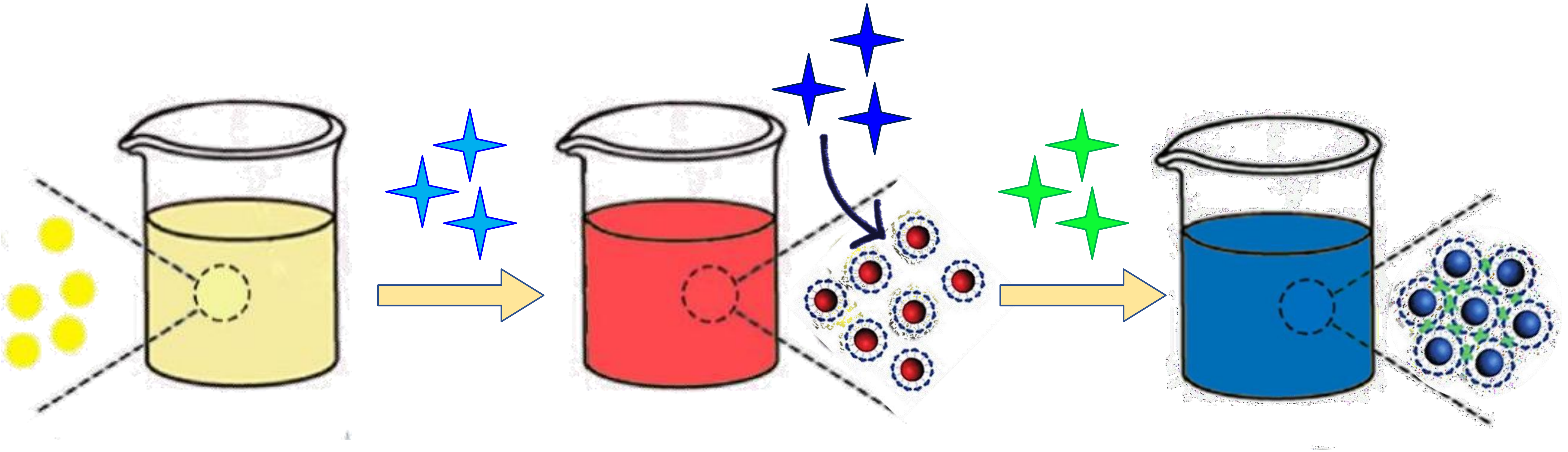
Sample	This work (mM)	RSD (%) ($n = 3$)	Glucometer (mM)	RSD (%) ($n = 3$)
1	4.83	2.69	4.70	4.26
2	7.30	4.46	7.53	3.34
3	8.79	4.82	8.97	1.70
4	10.36	3.09	10.23	2.46

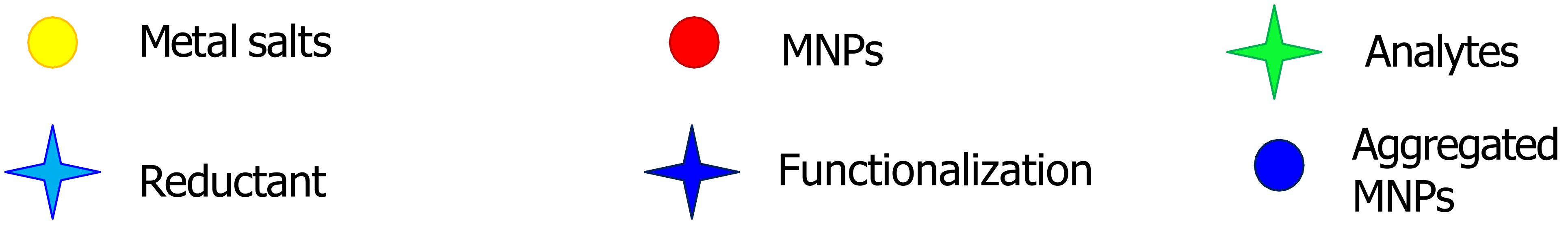
Metal nanoparticle aggregation



Metal nanoparticles aggregation

Main strategy





Metal nanoparticles aggregation

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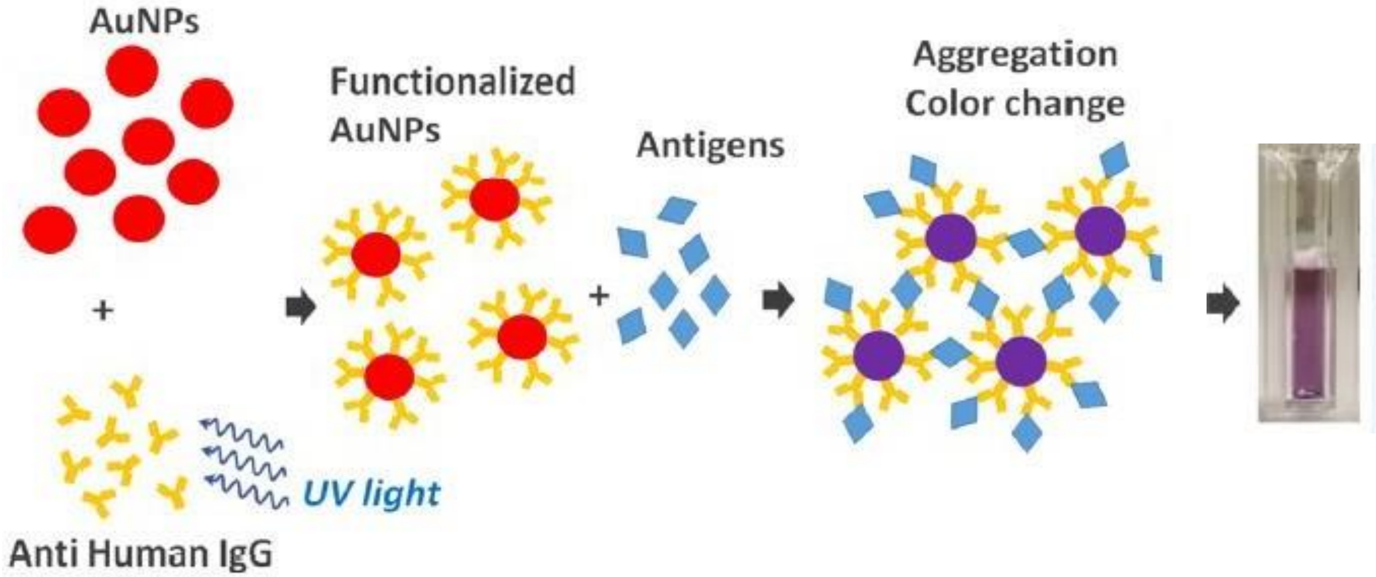
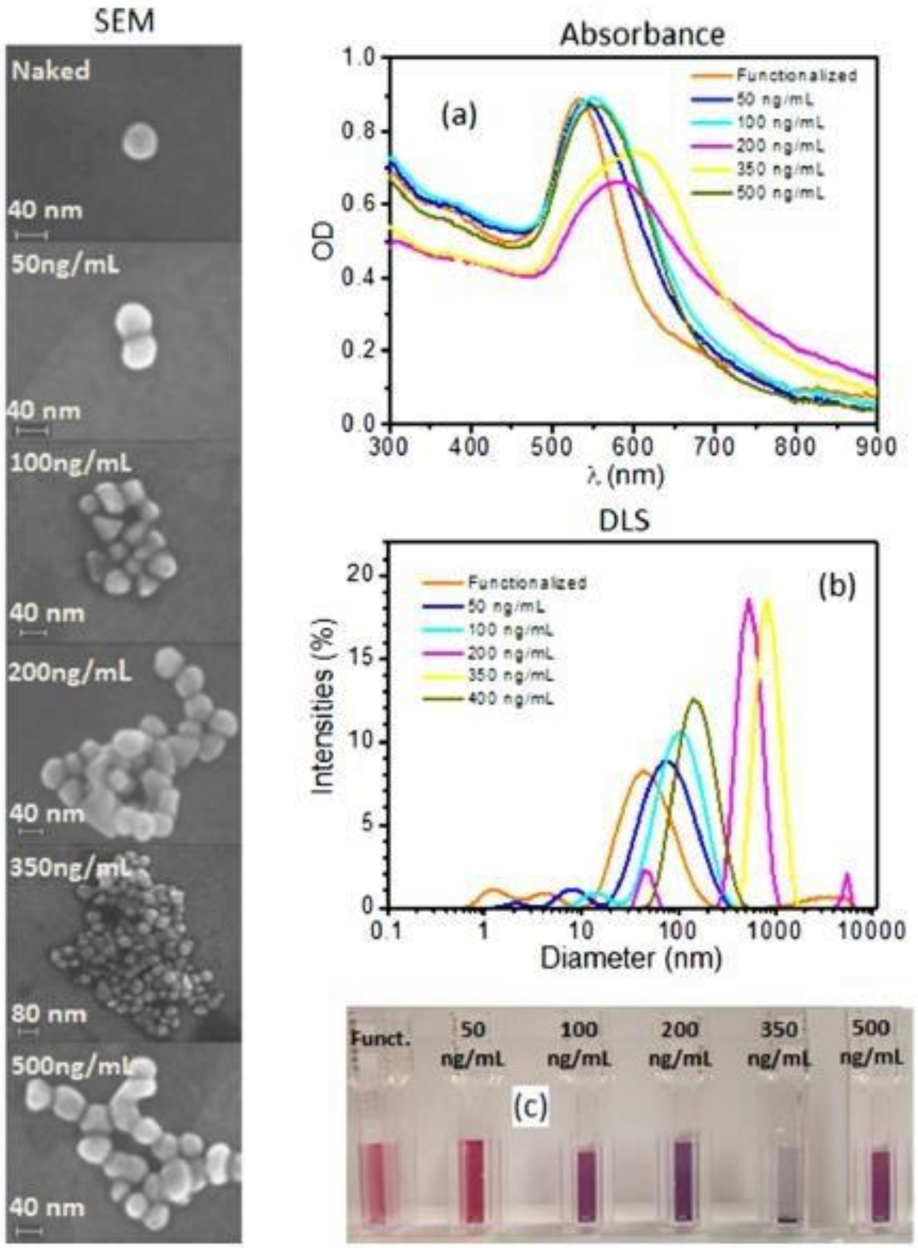
Immuno-based determination of HIgG





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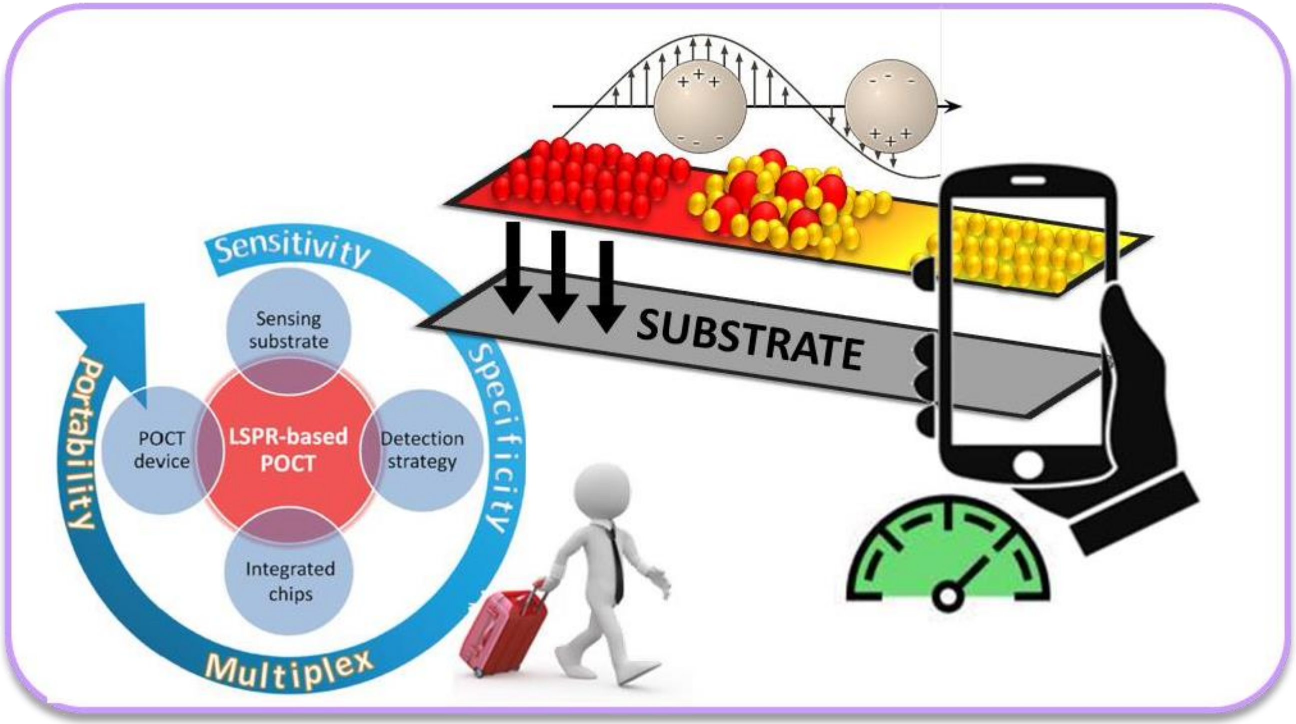
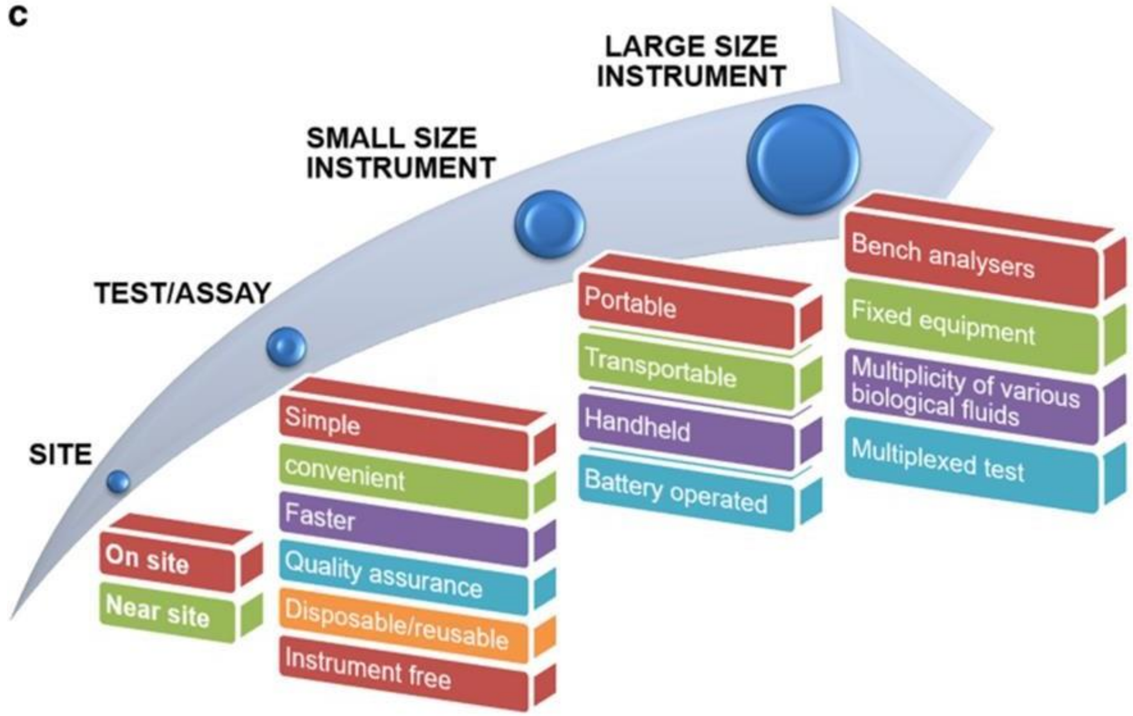
Colorimetric Immunosensor by Aggregation of Photochemically Functionalized Gold Nanoparticles

Marzia Iarossi,[†,∥] Chiara Schiattarella,[†,‡] Ilaria Rea,[‡] Luca De Stefano,[‡] Rosalba Fittipaldi,[§] Antonio Vecchione,[§] Raffaele Velotta,[*,†] and Bartolomeo Della Ventura[†]

Metal nanoparticles integration onto solid substrates

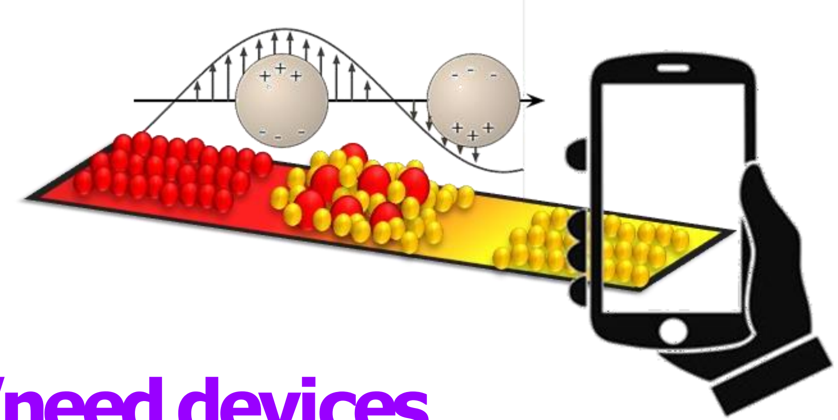




!!! Lab-on-a-strip Device !!!

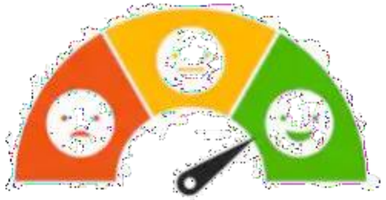
Metal nanoparticles integration onto solid substrates

Main Point of Care and Point On Needs device requirements



Point of care/need devices

A ffordable
S ensitive
S pecific
U ser friendly
2x R apid & robust
E quipment-free
D elivered



Cost performance

Manufacturing

Mass production

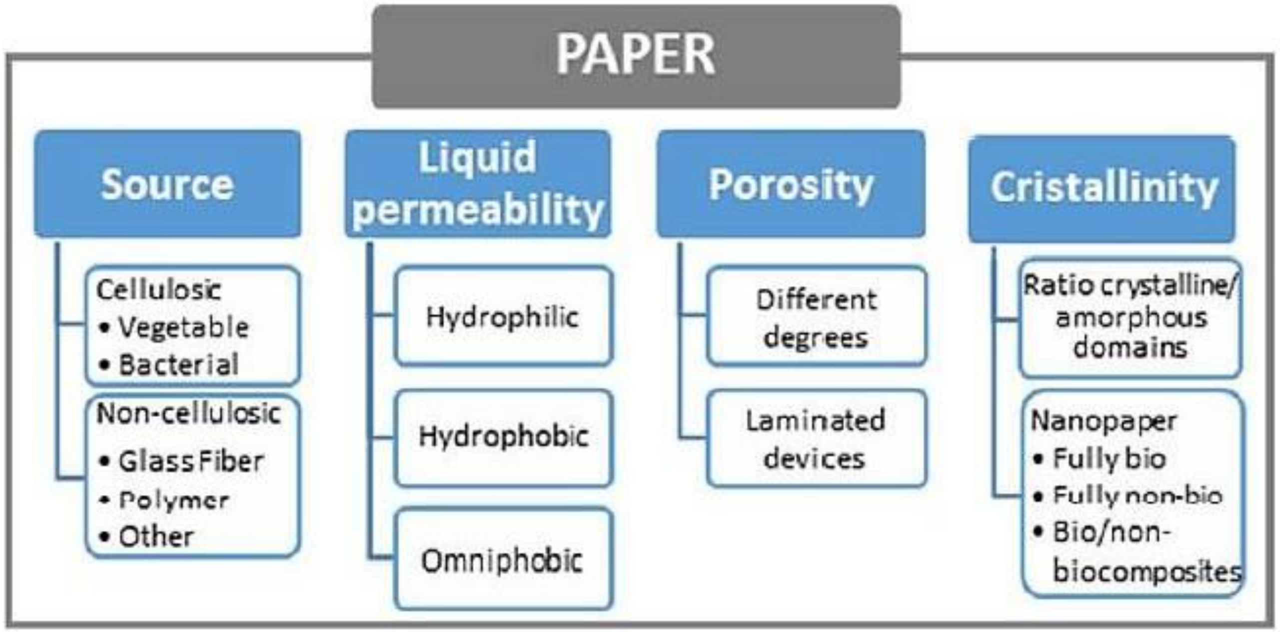
Paper as elective substrate

Paper as substrate

Paper can…
Store
Filter
React

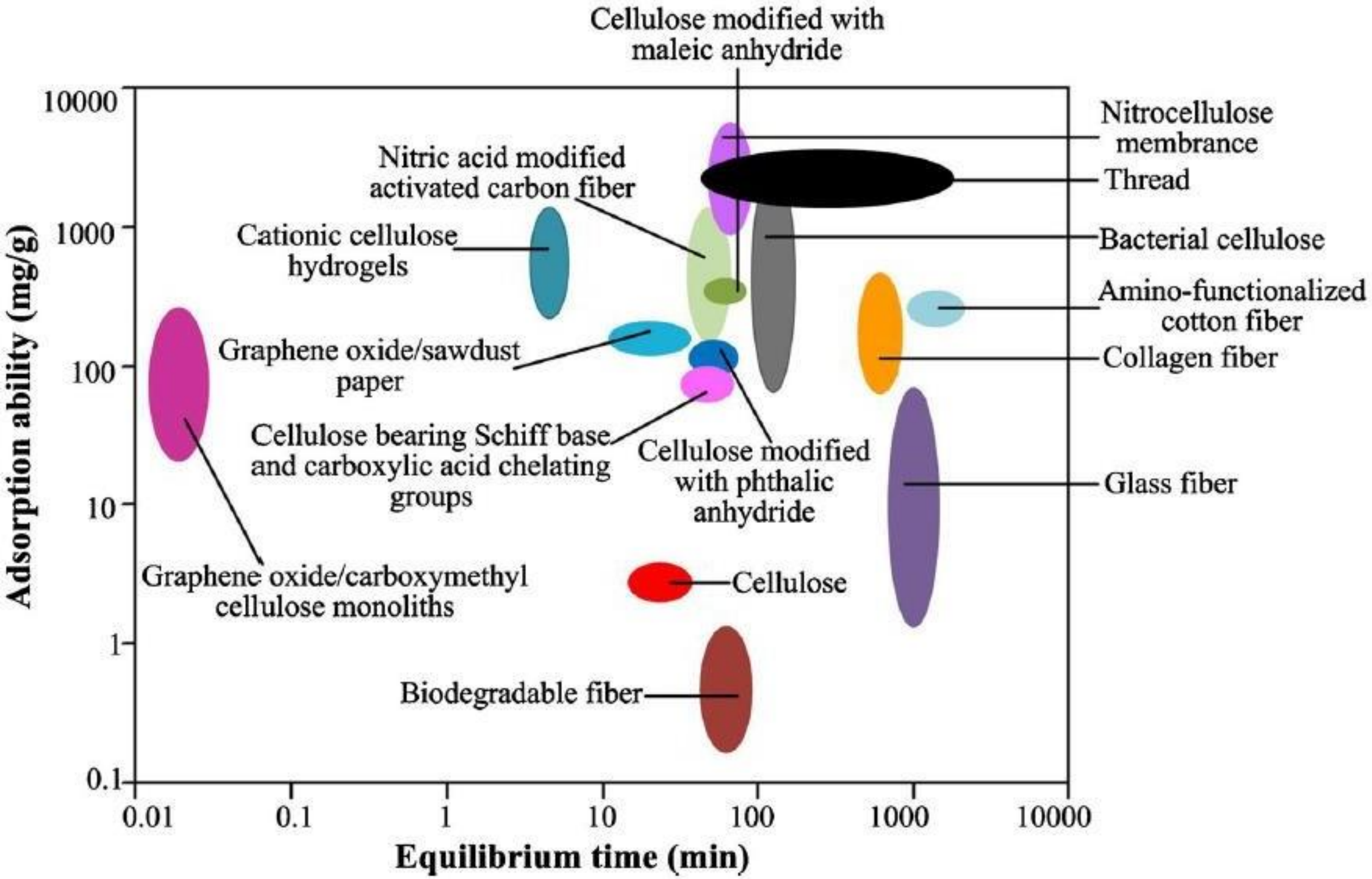
Drawbacks…
Reagents diffusion…
Electrical noise! ☹

An hydrophobic barrier is needed…



Paper as elective substrate

Kind of paper based substrates



Paper as elective substrate

Paper ca be tailored

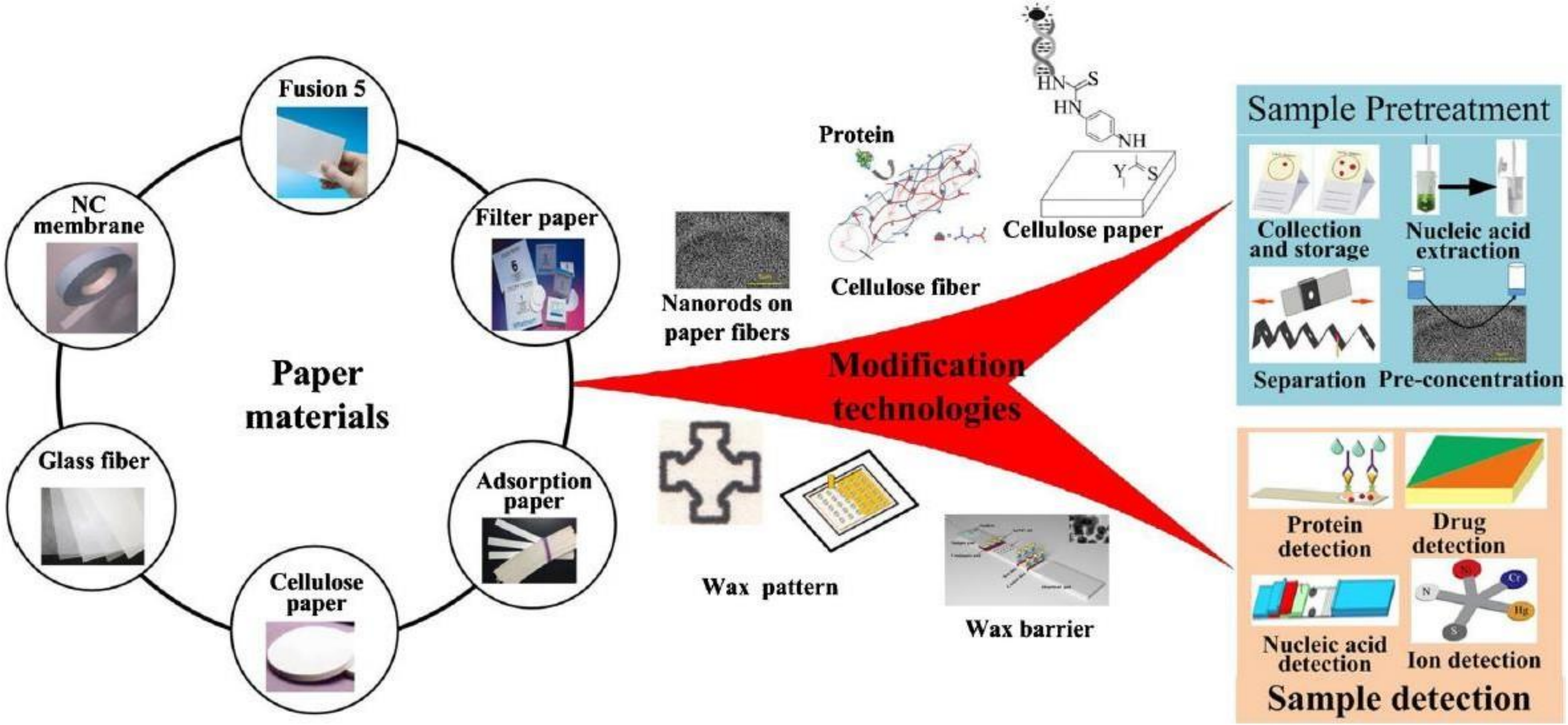
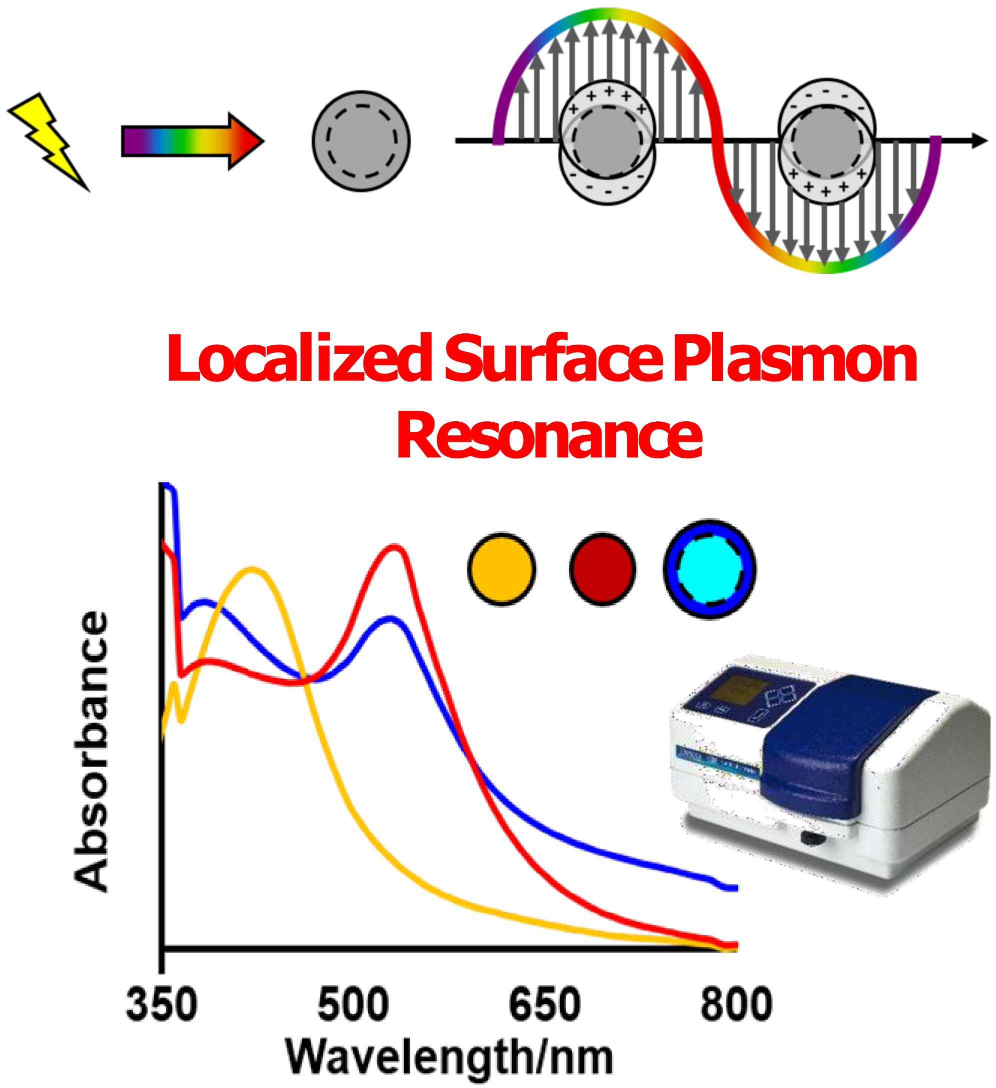
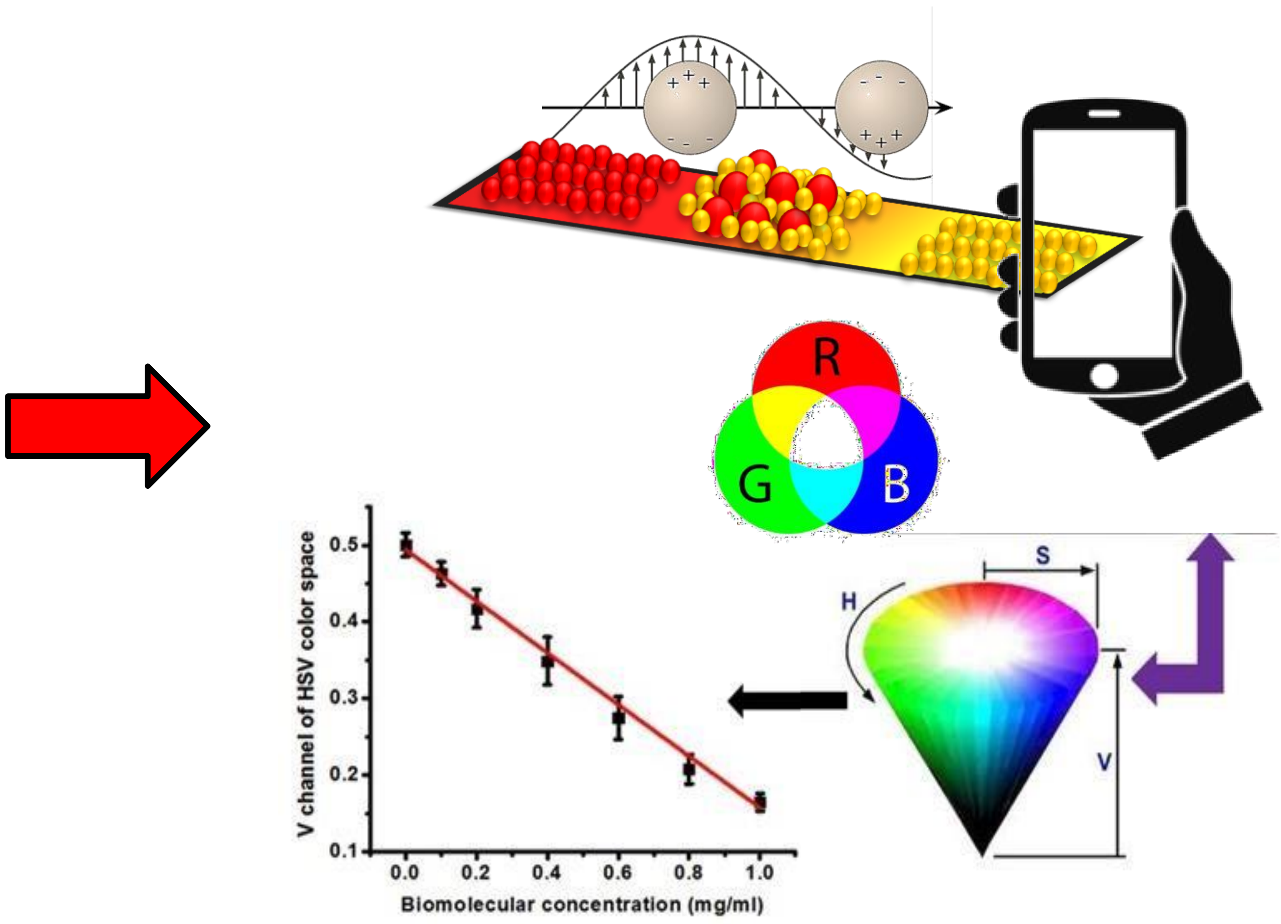


Fig. 1 Existing paper modification approaches for paper-based POCT. Different paper materials, including Fusion 5, filter paper, chromatography paper, cellulose paper, Whatman® No.1 filter paper and NC membrane, have been modified with various reagents for paper-based sample pretreatment and paper-based detection

Paper as elective substrate

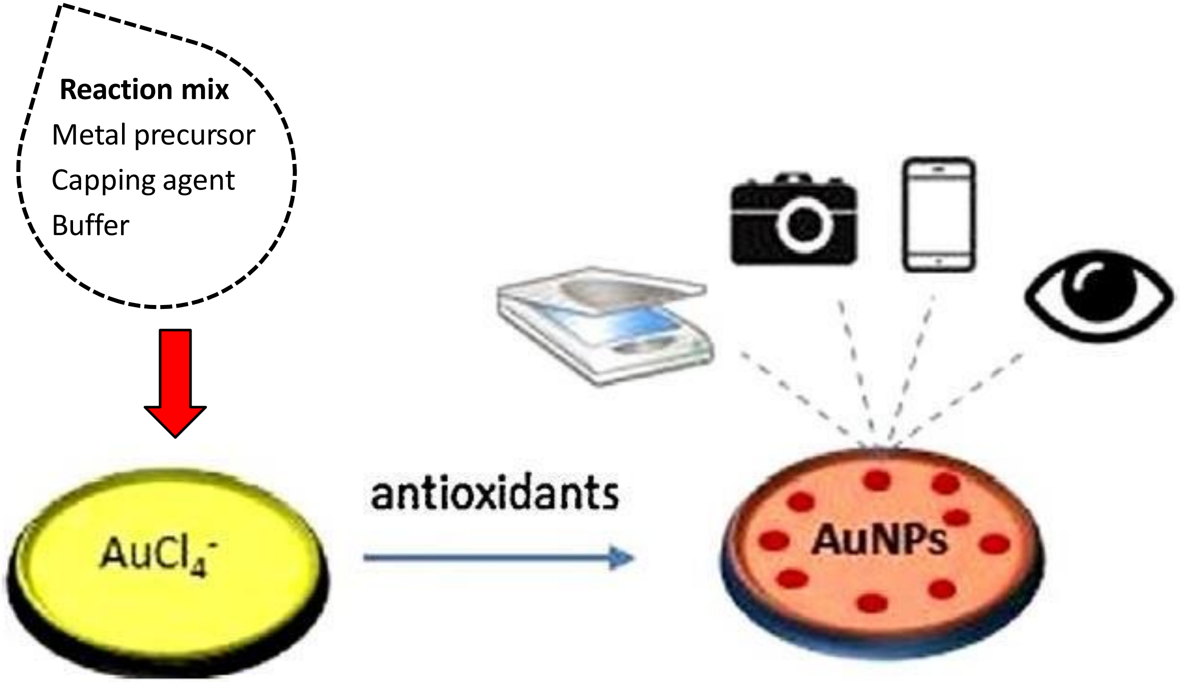
From plasmonic… Towards colorimetric strategies





Paper-based colorimetric sensor

Phenolic content and antioxidant capacity evaluation trough AuNPs formation

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Paper-based assay of antioxidant activity using analyte-mediated on-paper nucleation of gold nanoparticles as colorimetric probes

Tatiana G. Choleva, Foteini A. Kappi, Dimosthenis L. Giokas *, Athanasios G. Vlessidis

Paper-based colorimetric sensor

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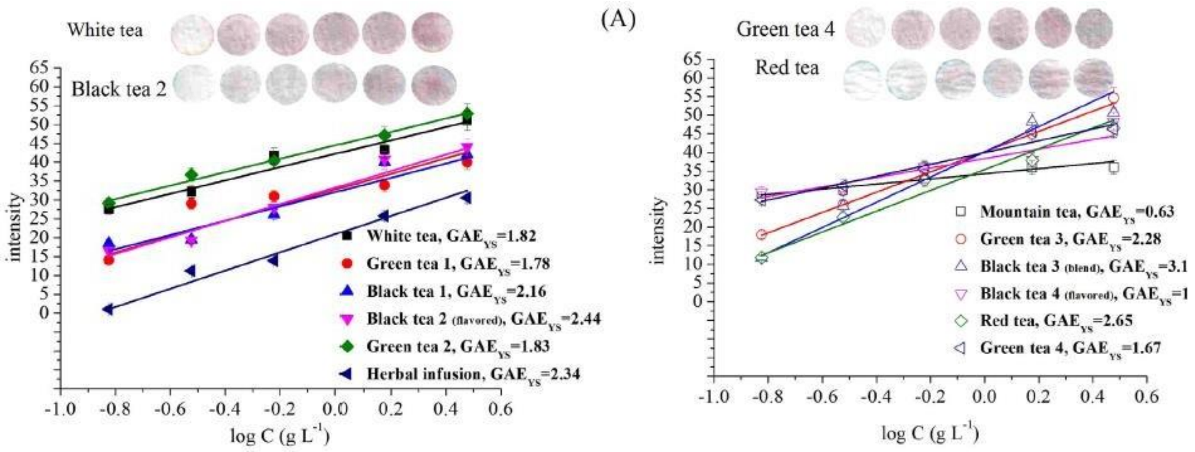
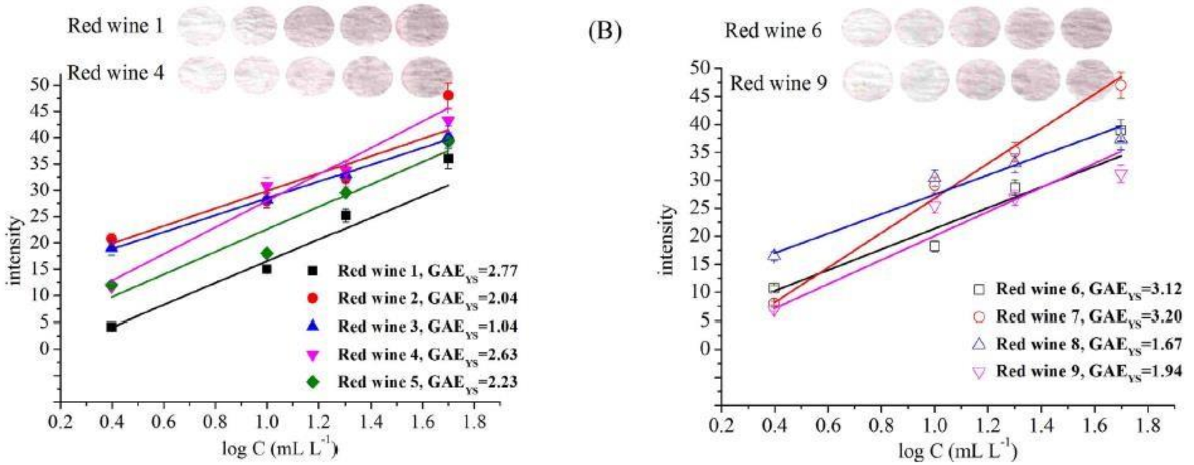
Phenolic content and antioxidant capacity evaluation trough AuNPs formation

Sample dose-response curve





Sample analysis

Evaluation of antioxidant activity of commercial teas by the Au–AuNP paper sensor and comparison with conventional assays. RSD range between 2.9 and 14.4%.

Tea sample	Au sensor Antioxidant activity (mg catechin g^{-1})	Au sensor Antioxidant activity (mg gallic acid g^{-1})	Folin–Ciocalteu Total phenolic content (mg gallic acid g^{-1})	CUPRAC Total antioxidant activity (mg Trolox g^{-1})	Aluminum assay Total flavonoid content (mg catechin g^{-1})
White tea	59.49	6.52	91.00	196.54	31.63
Green tea 1	56.81	5.76	95.30	208.61	26.76
Black tea 1	39.09	2.10	42.46	95.01	15.06
Black tea 2 (flavored)	24.26	0.58	52.72	114.28	18.47
Green tea 2	59.19	6.43	100.83	232.42	31.63
Herbal infusion	14.27	0.14	33.58	67.04	16.04
Mountain tea	60.44	6.80	31.54	67.83	21.88
Green tea 3	89.78	19.80	79.43	180.87	24.32
Black tea 3 (blend)	55.86	5.50	41.44	97.52	16.52
Black tea 4 (flavored)	44.12	2.91	69.83	147.97	23.35
Red tea	38.03	1.95	52.29	119.45	22.37
Green tea 4	120.60	43.93	107.53	231.87	60.87

Paper-based colorimetric sensor

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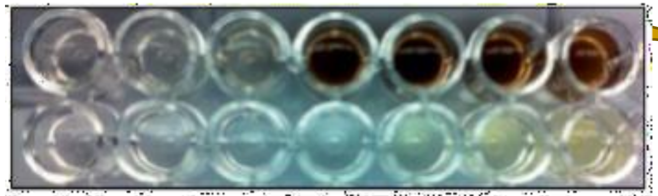
Phenolic content and antioxidant capacity evaluation trough NanoCeria formation

$[CeO_2]$ 0.0025, 0.005, 0.01, 0.1, 1, 2, and 4%

Optimization



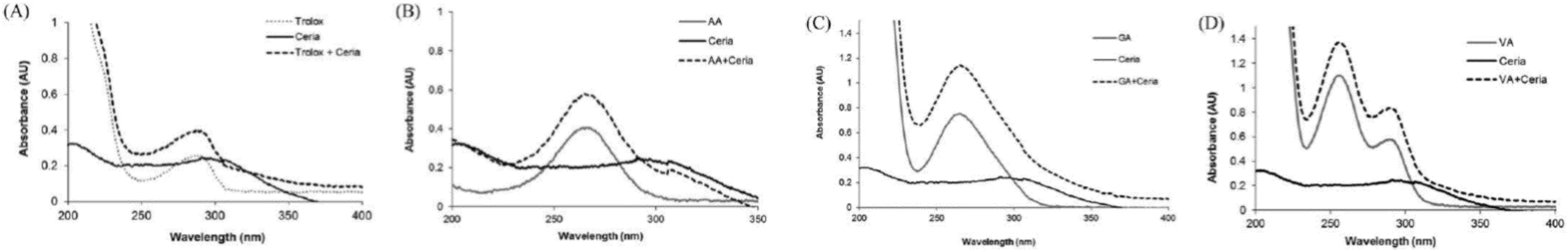
Caffeic acid (0,45 mM) reacted $[CeO_2]$

$[CeO_2]$= 4%


Analyst RSCPublishing
PAPER View Article Online
Cite this: DOI: 10.1039/c2an36205b
Portable ceria nanoparticle-based assay for rapid detection of food antioxidants (NanoCerac)
Erica Sharpe, Thalia Frasco, Daniel Andreescu and Silvana Andreescu*

Uv-vis spectra of ceria nanoparticles dispersion (13 ppm) in the presence and abesence of selected antioxidants.

Trolox | Ascorbic acid | Gallic acid | Vanillic acid



$2\ CeO_2 + 3\ C_6H_8O_6 \rightarrow Ce_2O_3 + 3\ C_6H_6O_6 + 2\ H_2O$

From dispersed system

to paper support

Paper-based colorimetric sensor

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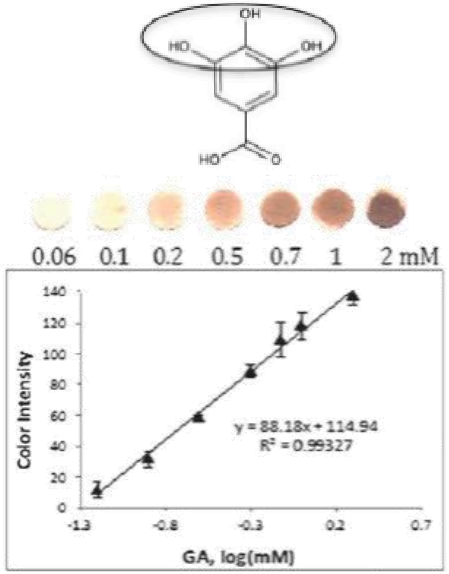
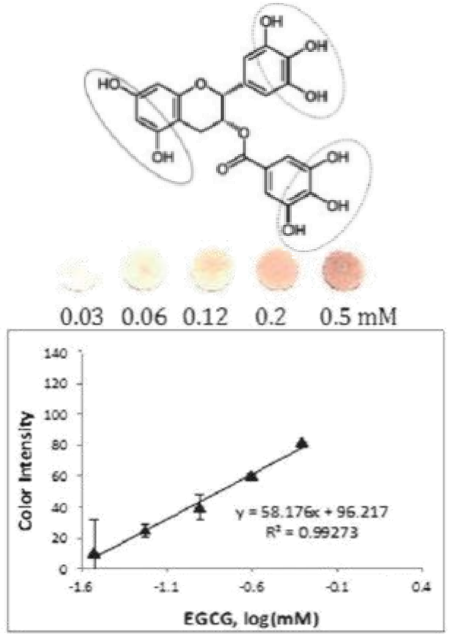
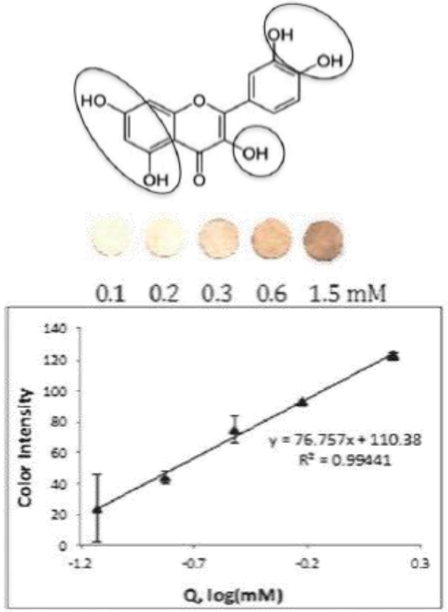
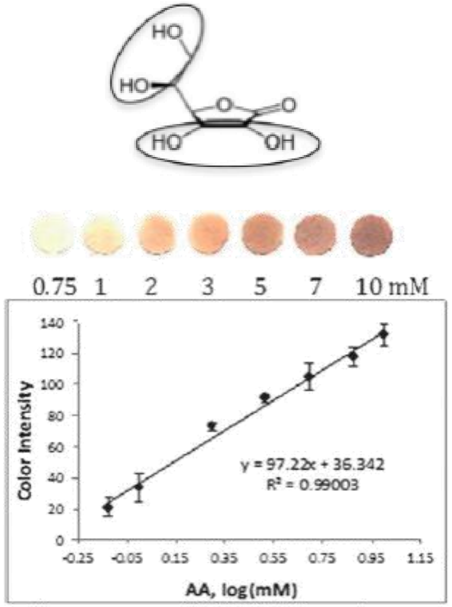
Phenolic content and antioxidant capacity evaluation trough NanoCeria formation

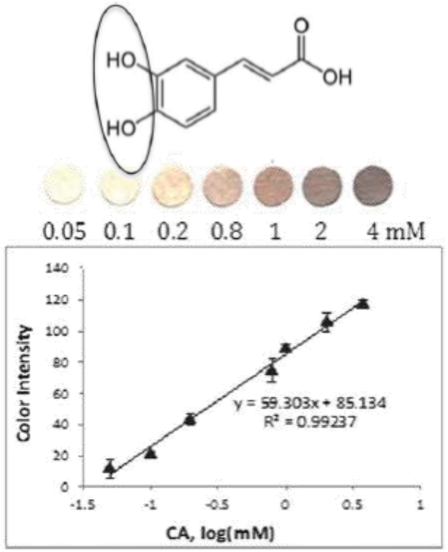
Dose-response curve

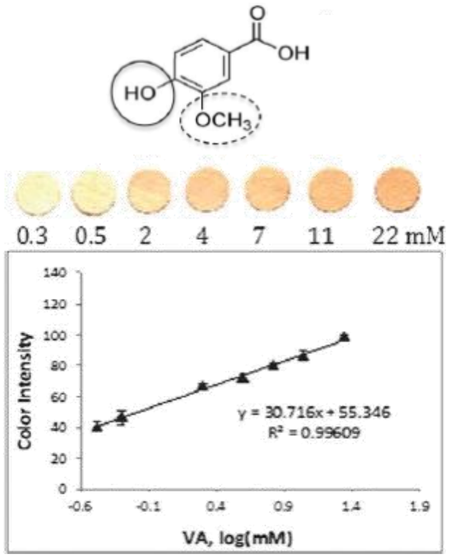




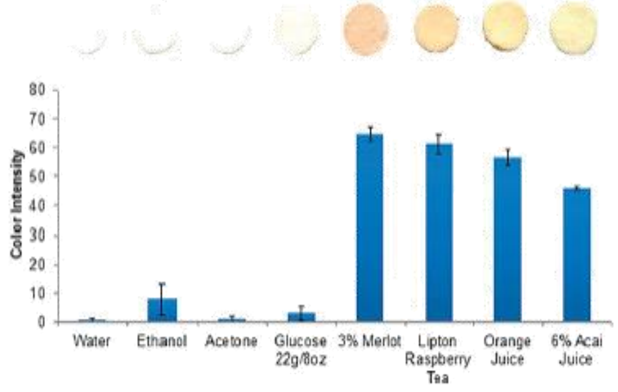








Interferents evaluation



Tested interfering compounds

Common lab solvent:
- water,
- ethanol,
- acetone

Common sugar presents in:
- juice,
- wine,
- commercial teas

Paper-based colorimetric sensor

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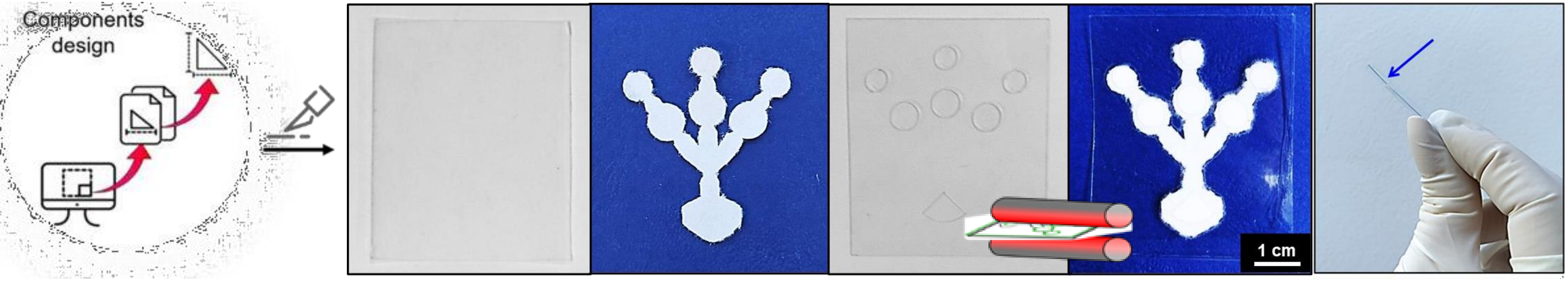
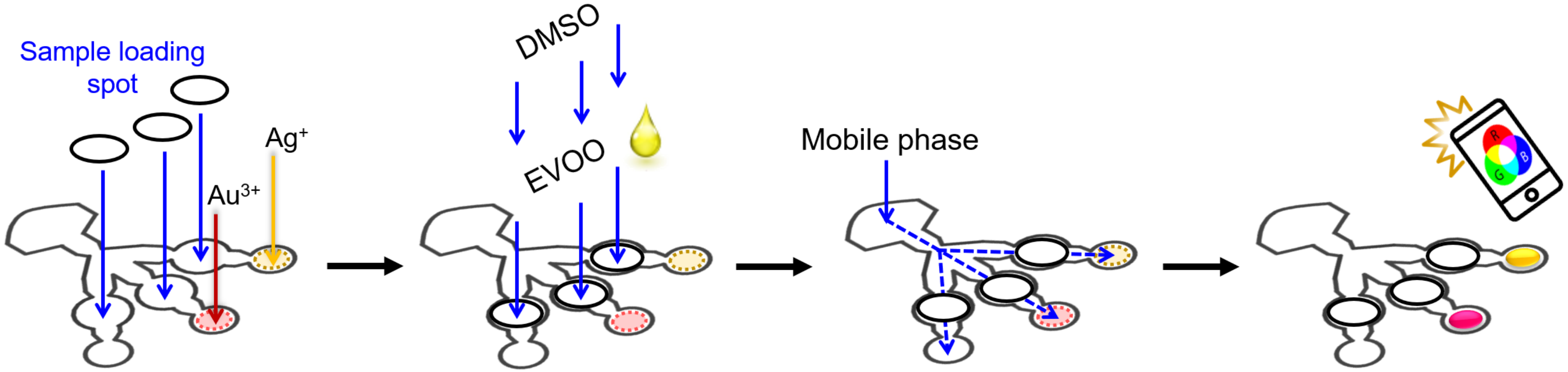
Extraction-free olive oil phenolic compounds evaluation trough a seed growth strategy

Lab-on-a-strip fabrication

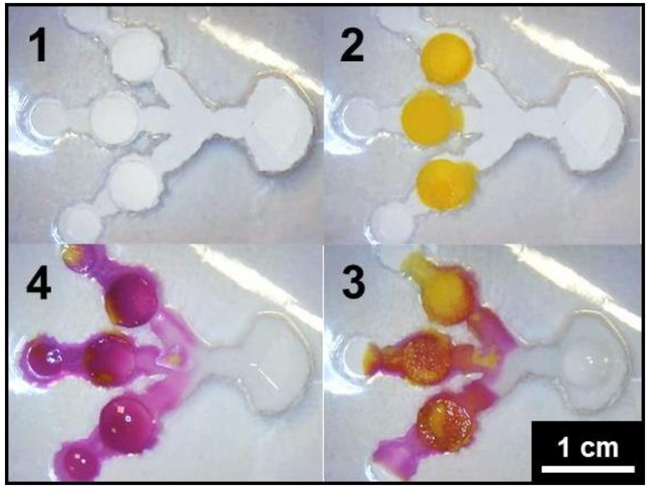


Assay format



Total assay volume: ~ 80 uL

Assay simulation with a colorimetric dye



Paper-based colorimetric sensor

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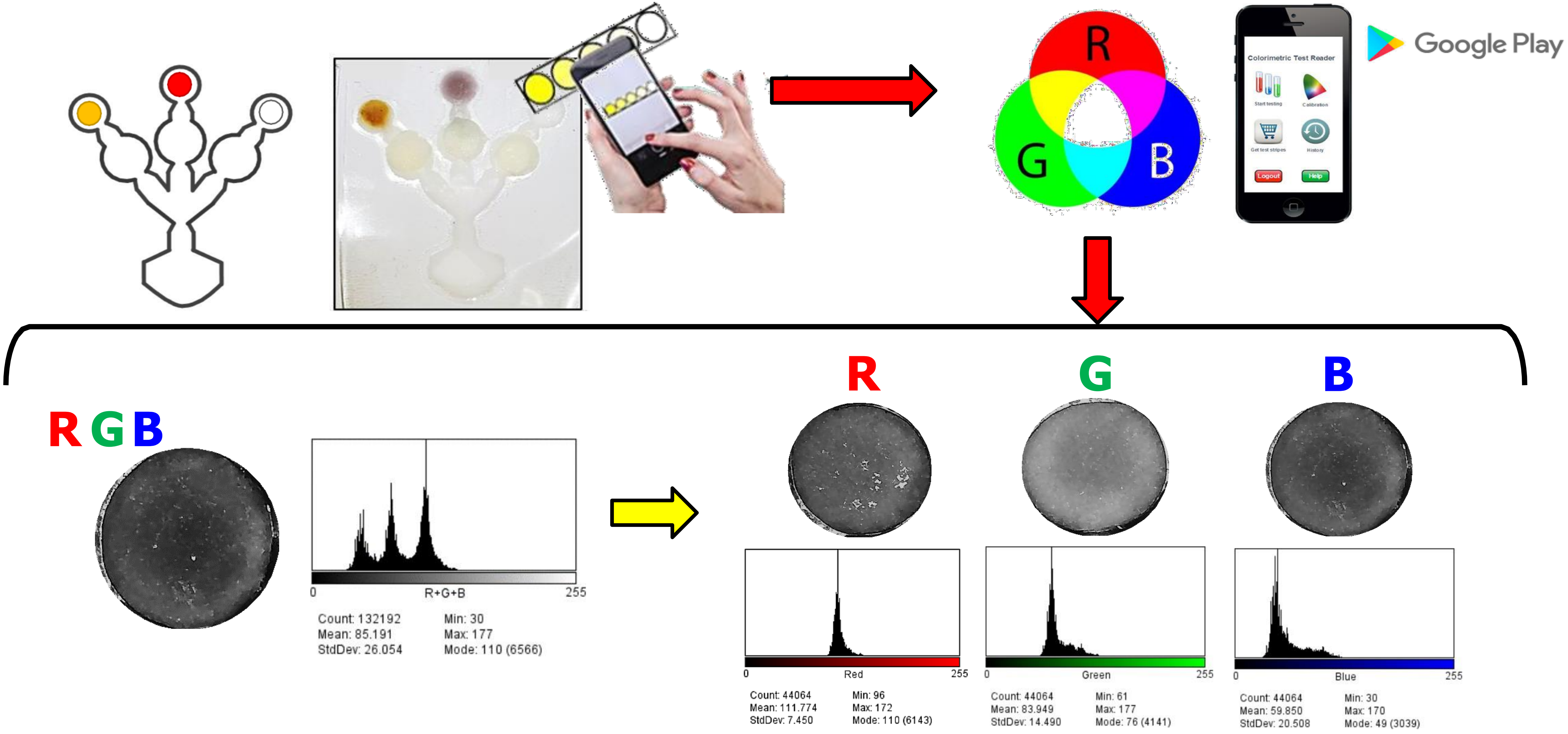
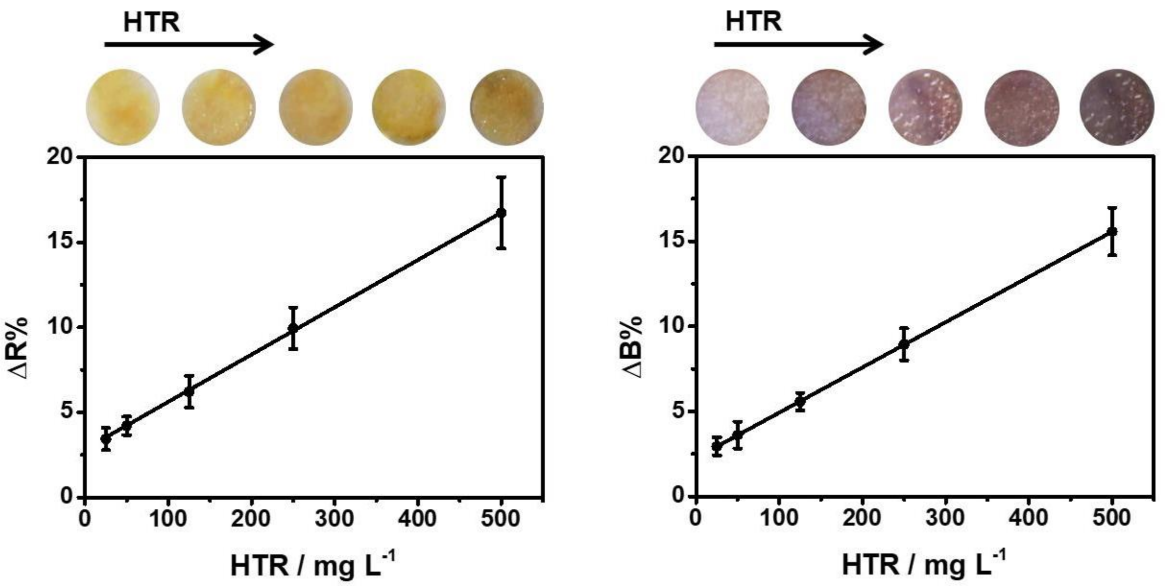
Extraction-free olive oil phenolic compounds evaluation trough a seed growth strategy
Color analysis



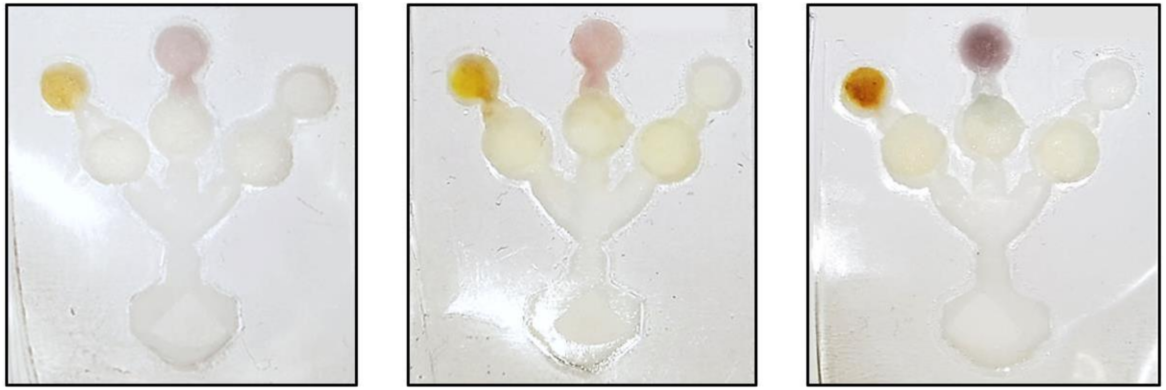
Paper-based colorimetric sensor

Extraction-free olive oil phenolic compounds evaluation trough a seed growth strategy

Dose-response curve

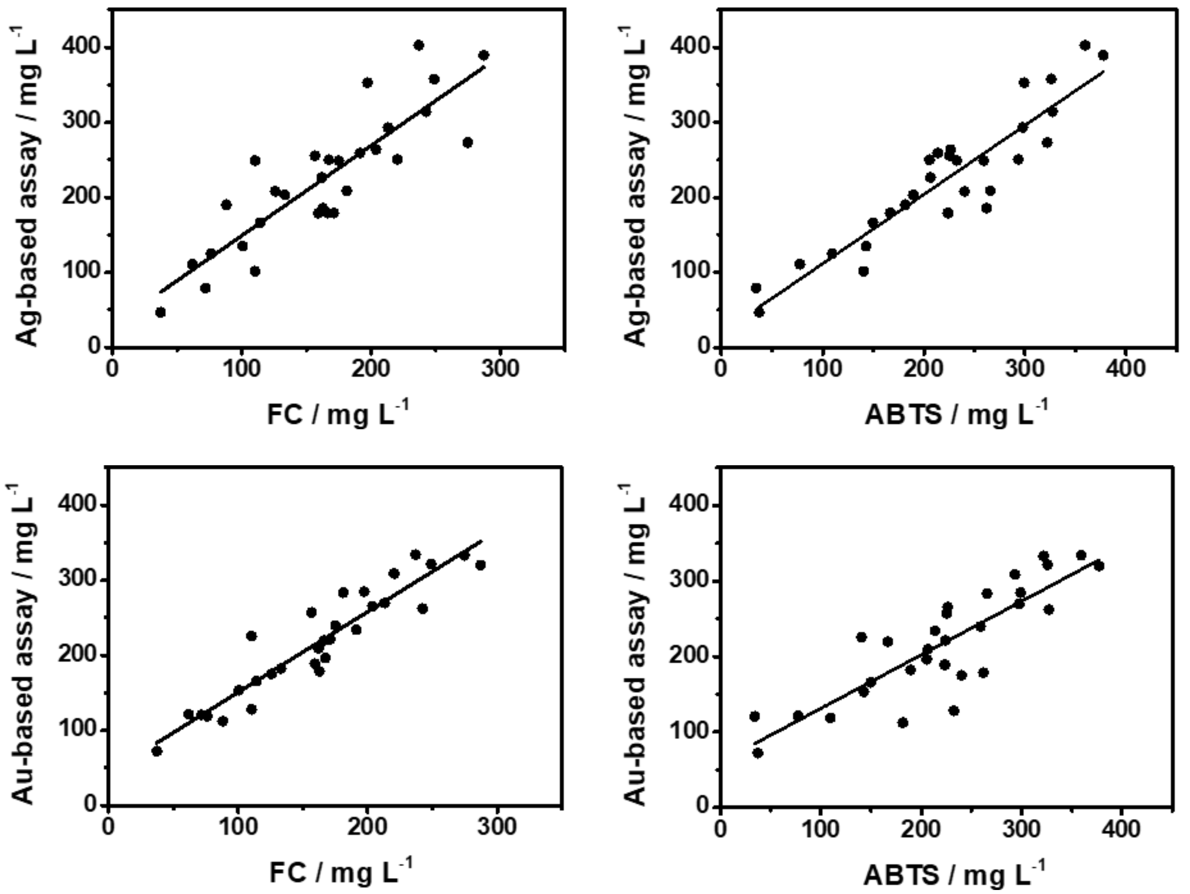


EVOO samples’ phenolyc compounds content



Low Mean High

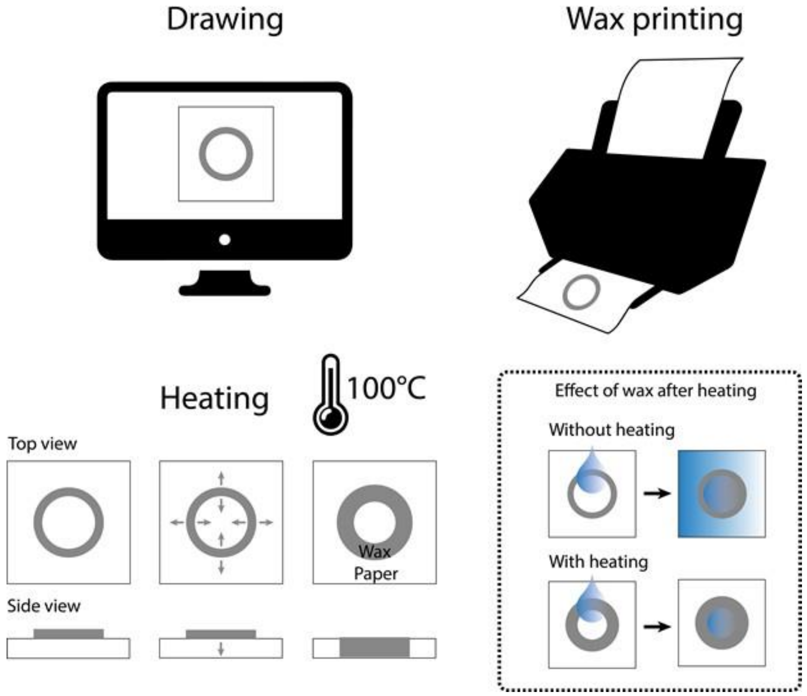
Sample analysis, analytical performances

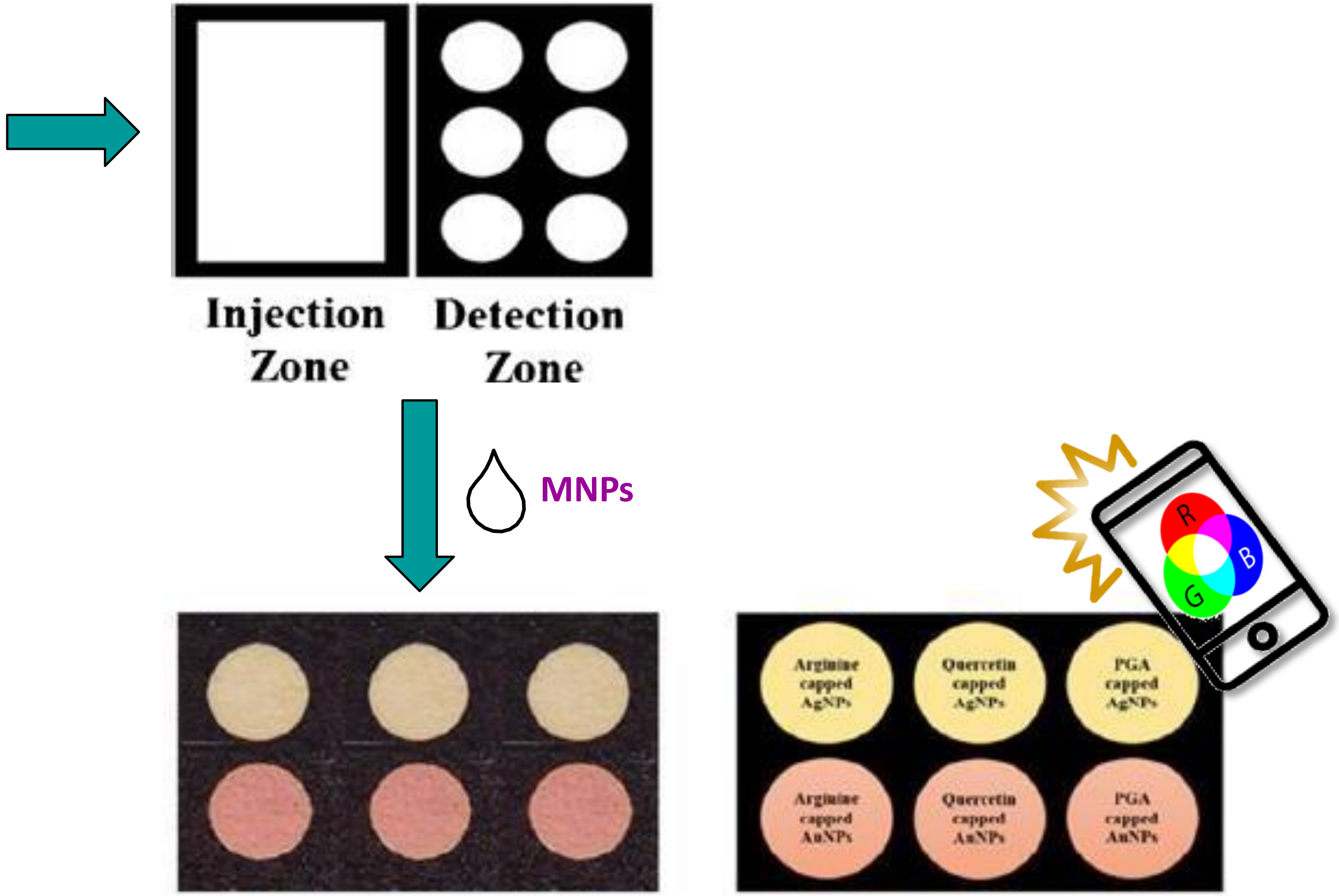


No interterferences by compounds commonly present in EVOO

Paper-based colorimetric sensor

Pesticides determination trough MNPs aggregation integrated in a paper-based device





Microchimica Acta (2020) 187:621
https://doi.org/10.1007/s00604-020-04596-x

ORIGINAL PAPER

A paper-based colorimetric sensor array for discrimination and simultaneous determination of organophosphate and carbamate pesticides in tap water, apple juice, and rice

Mohammad Mahdi Bordbar[1] · Tien Anh Nguyen[2] · Fabiana Arduini[3] · Hasan Bagheri[1]

Paper-based colorimetric sensor

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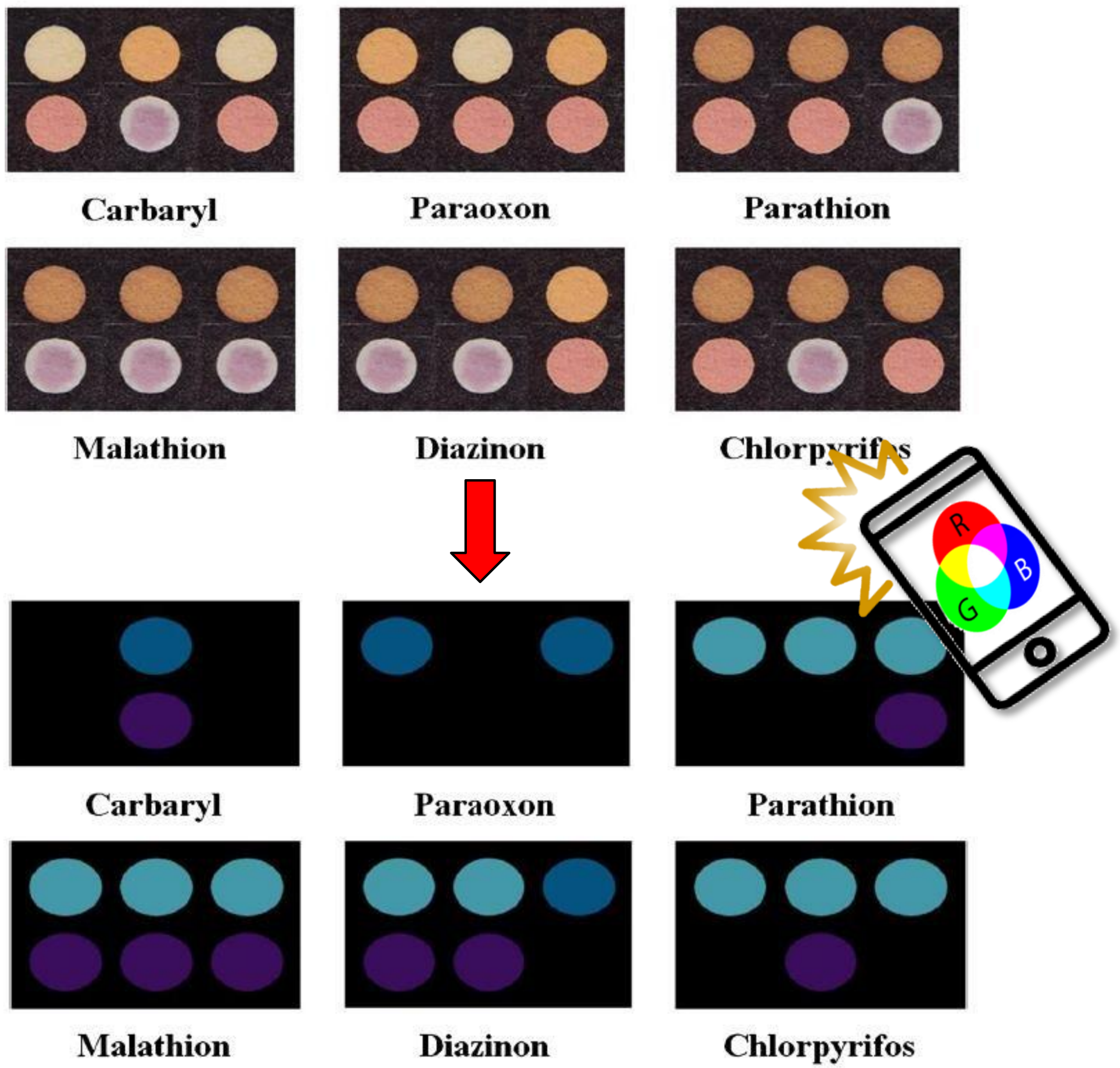
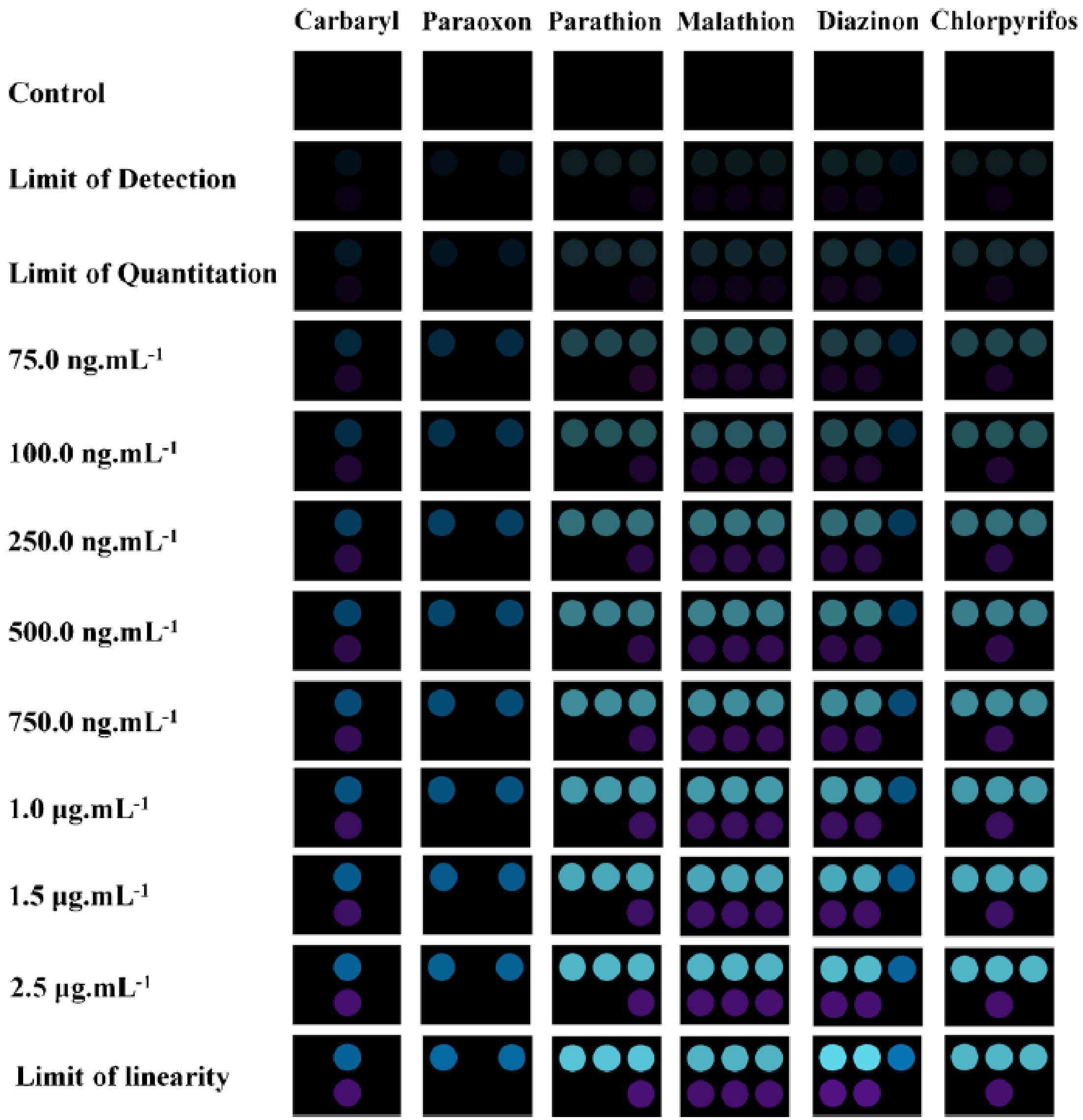
Pesticides determination trough MNPs aggregation integrated in a paper-based device

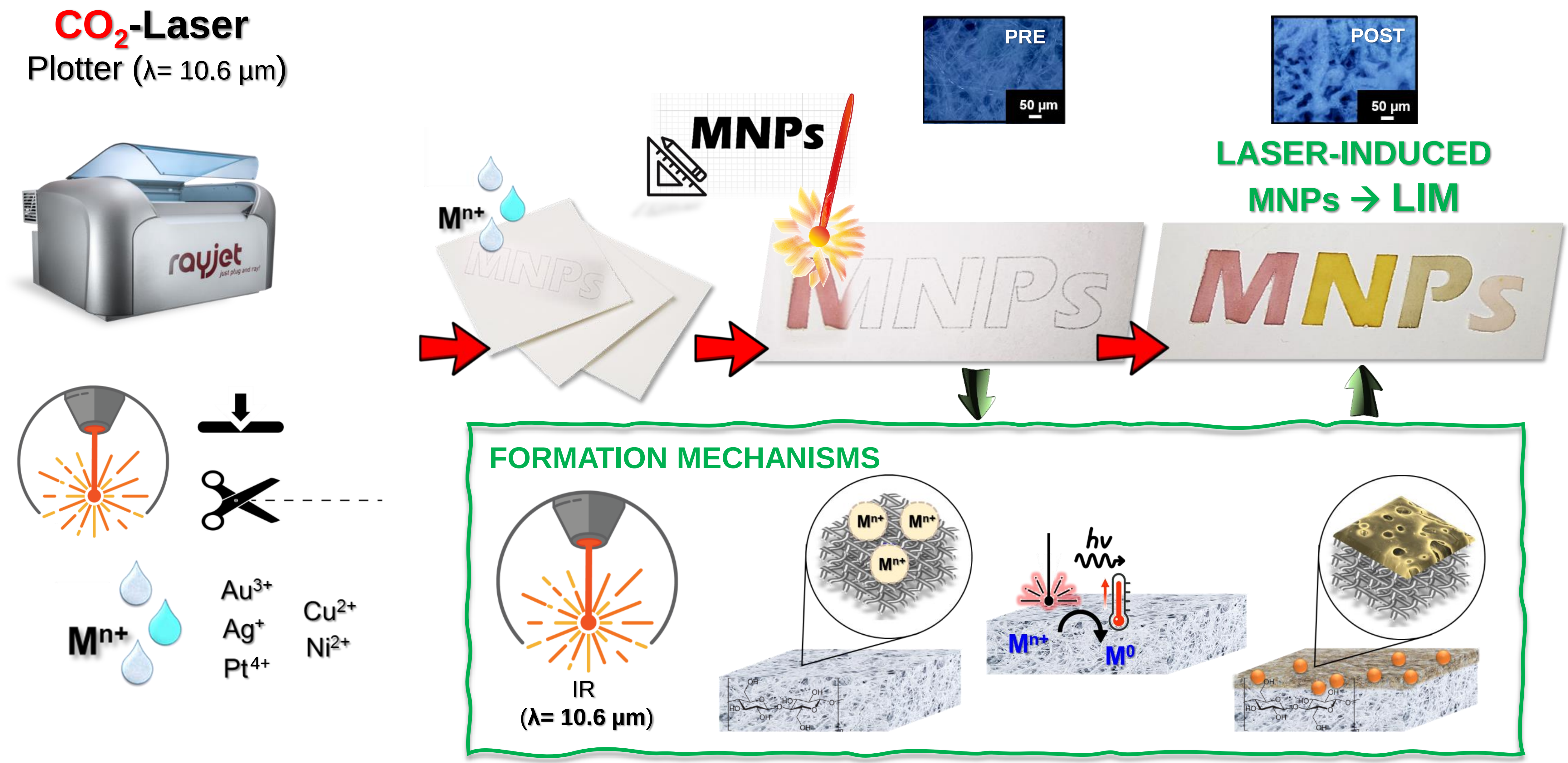
Analytes screening



Dose-response curve and analytical parameters



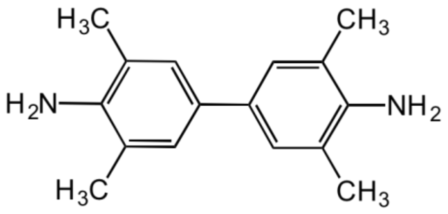
Strategy: Laser-Induced Metal Nanoparticles (LIM)



LIM: Colorimetric determination of Ascorbic Acid

Sensing layer: GF_{TMB}

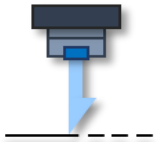
3,3',5,5'-Tetramethylbenzidine (TMB)

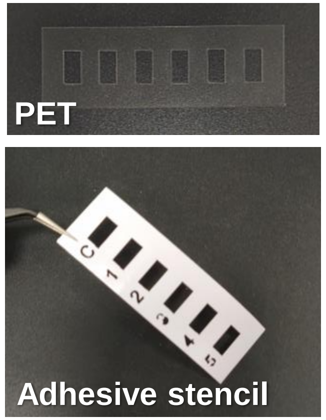


Device manufacturing

1) Modules fabbrication

Cutting plotter

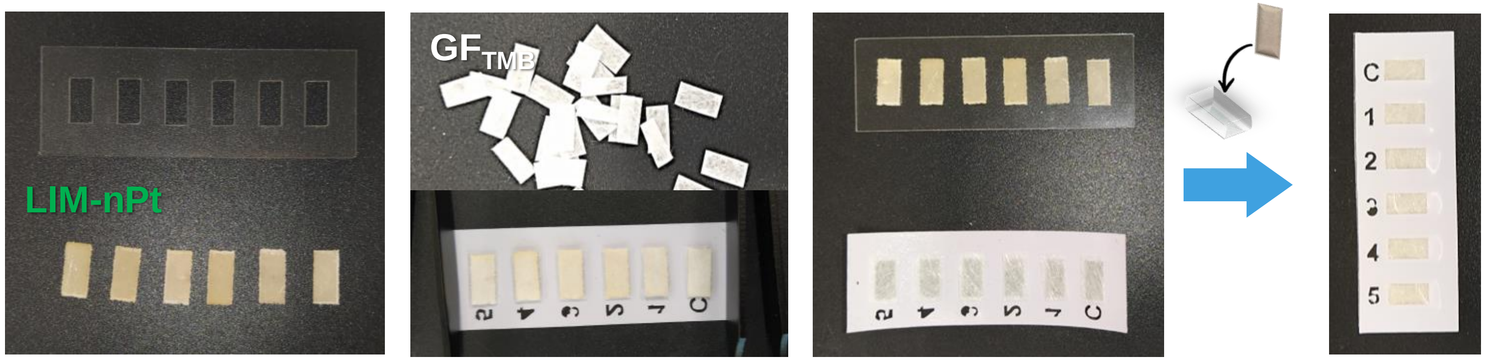




2) nanoCatalysts and Sensing layers assembling

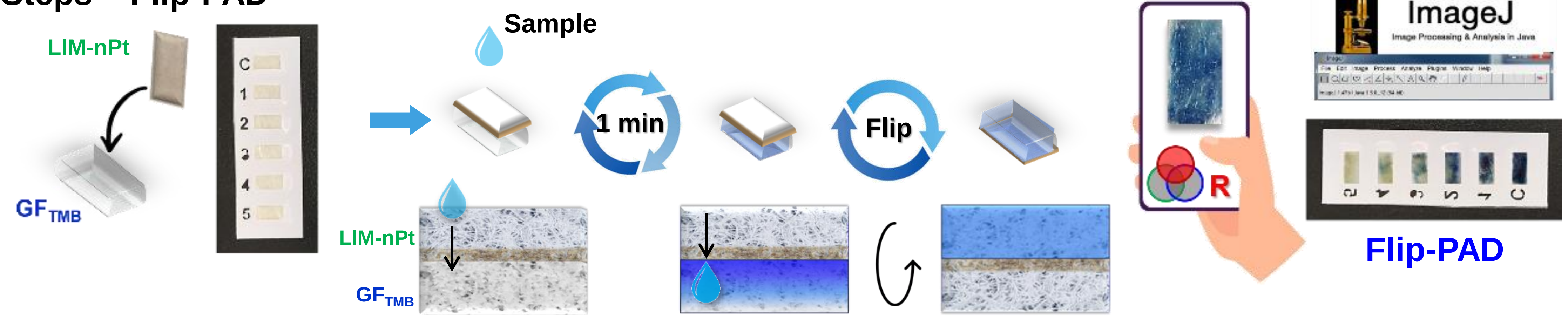
Modules alignment

Modules assembling

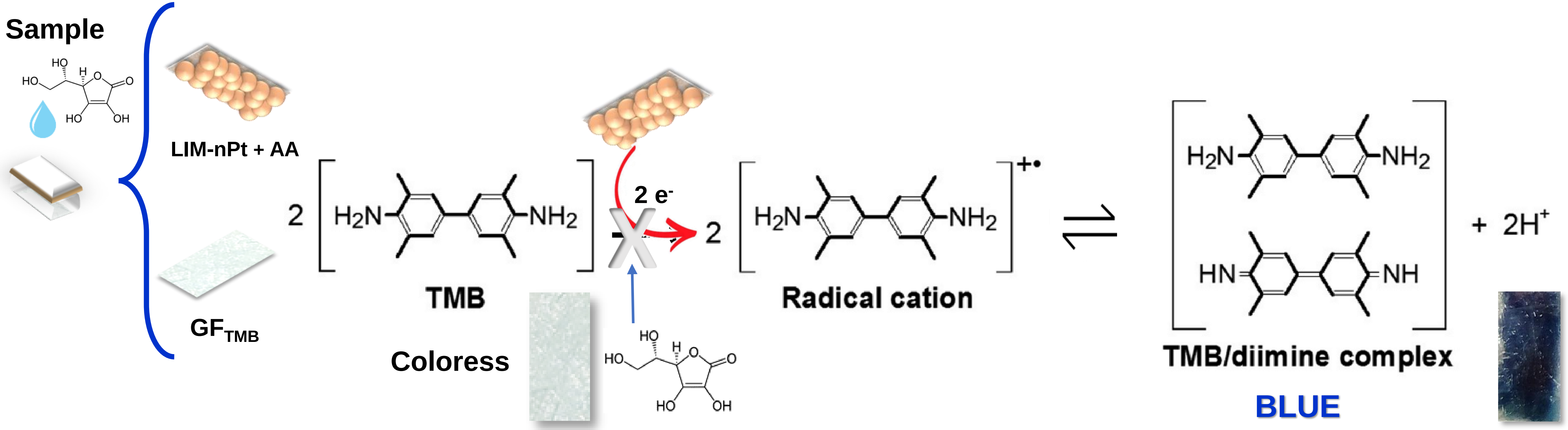


LIM: Colorimetric determination of Ascorbic Acid

Assay Steps – Flip-PAD



Sensing strategy



LIM: Colorimetric determination of Ascorbic Acid

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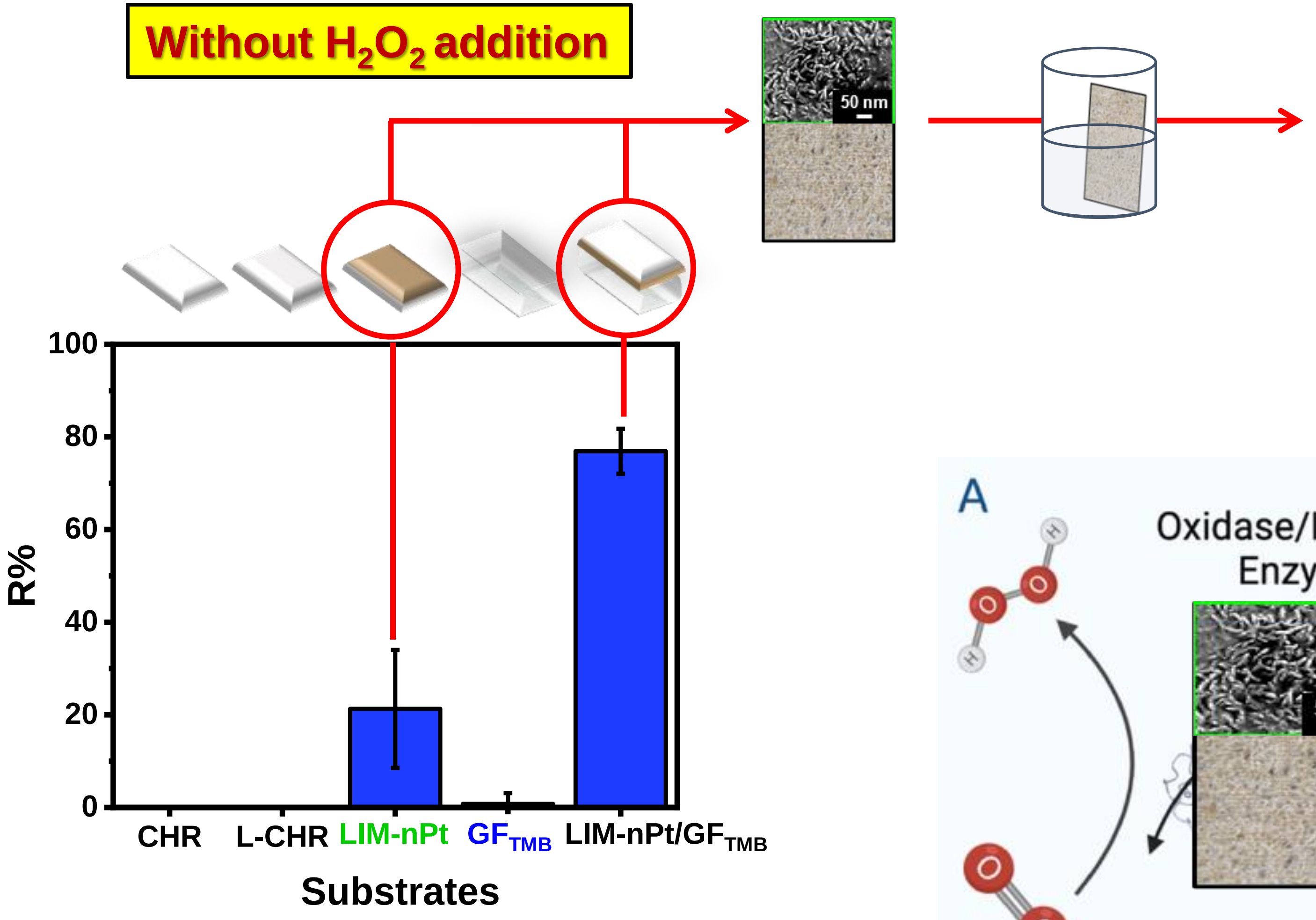
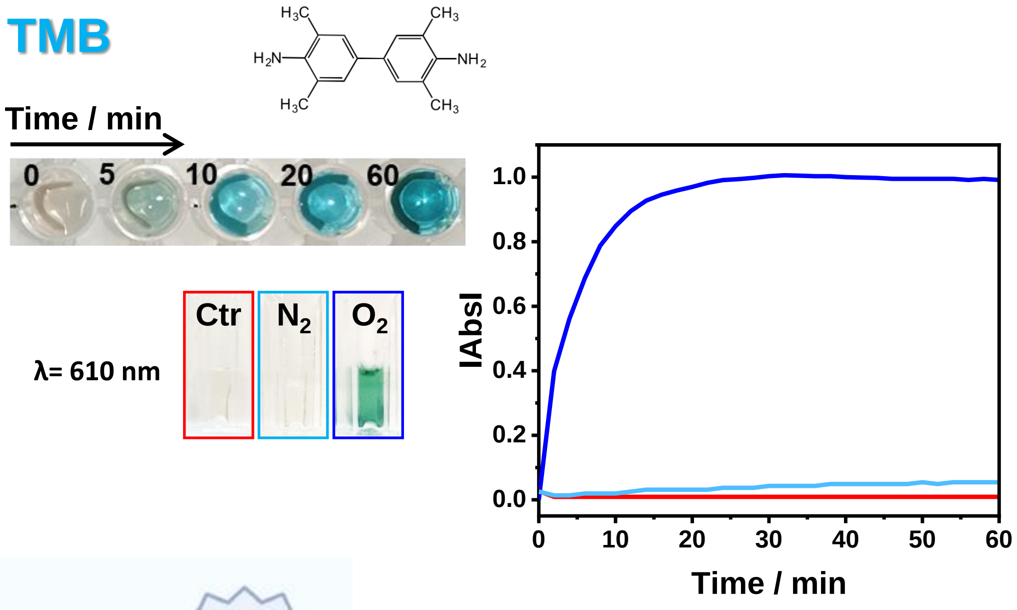
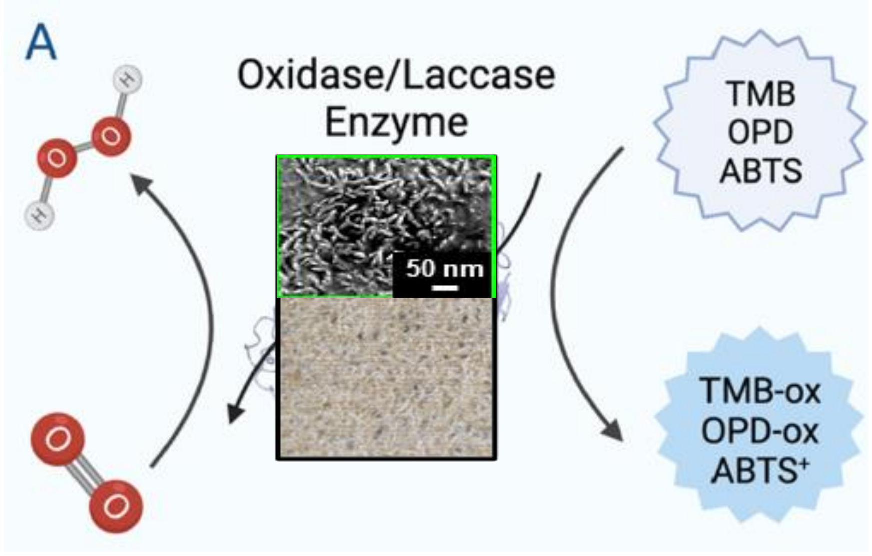
Sensing strategy and <u>Nanozyme</u> mechanisms hypotesis

Without H_2O_2 addition

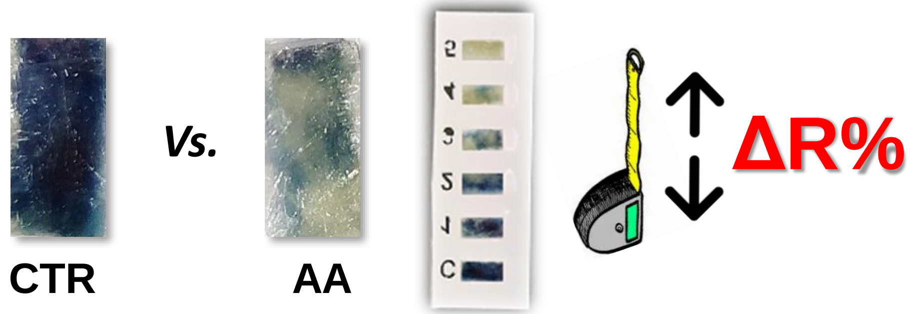




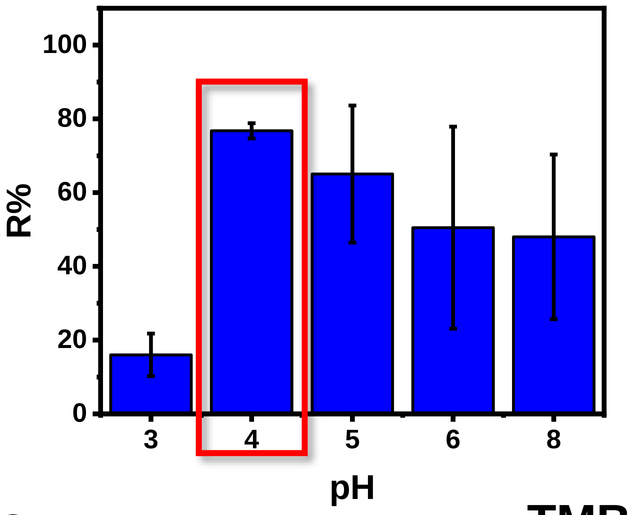


LIM: Colorimetric determination of Ascorbic Acid

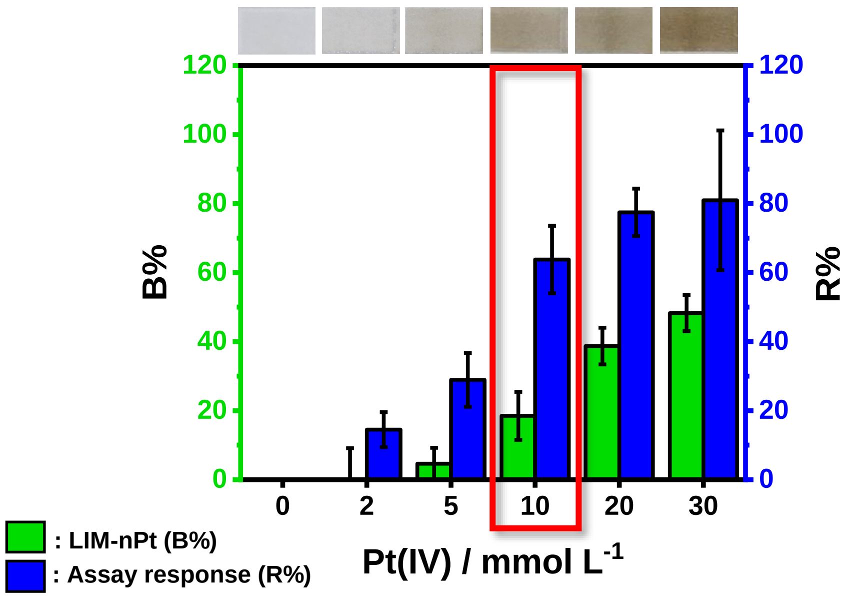
Assay development



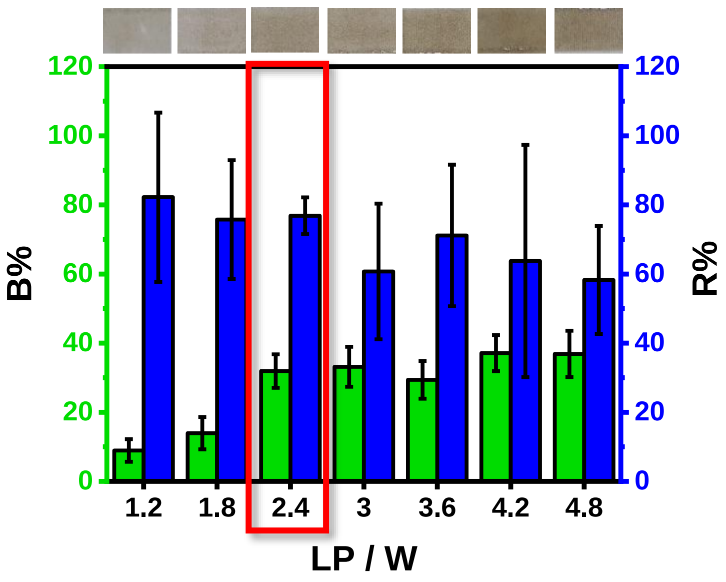
Reaction conditions



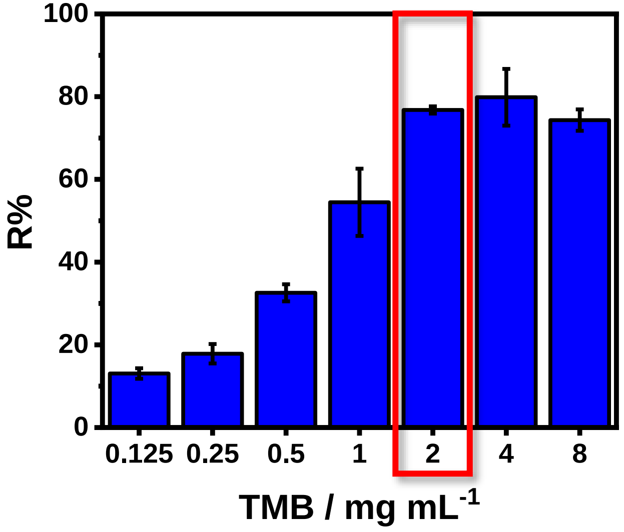
Pt amount



LIM-nPt synthesis



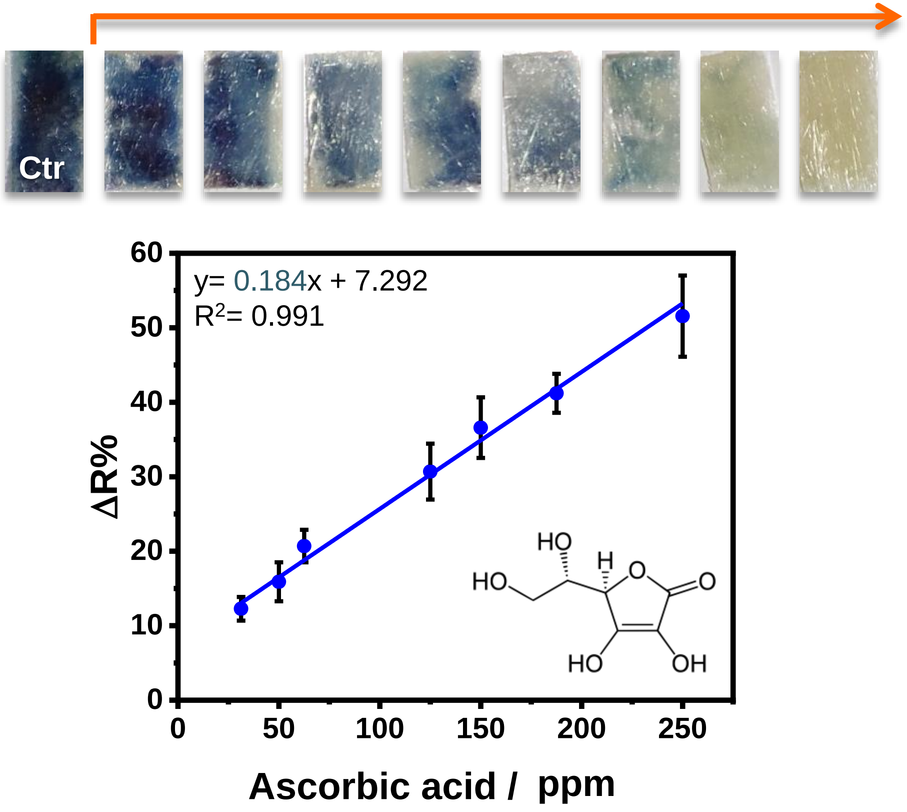
TMB amount



LIM: Colorimetric determination of Ascorbic Acid

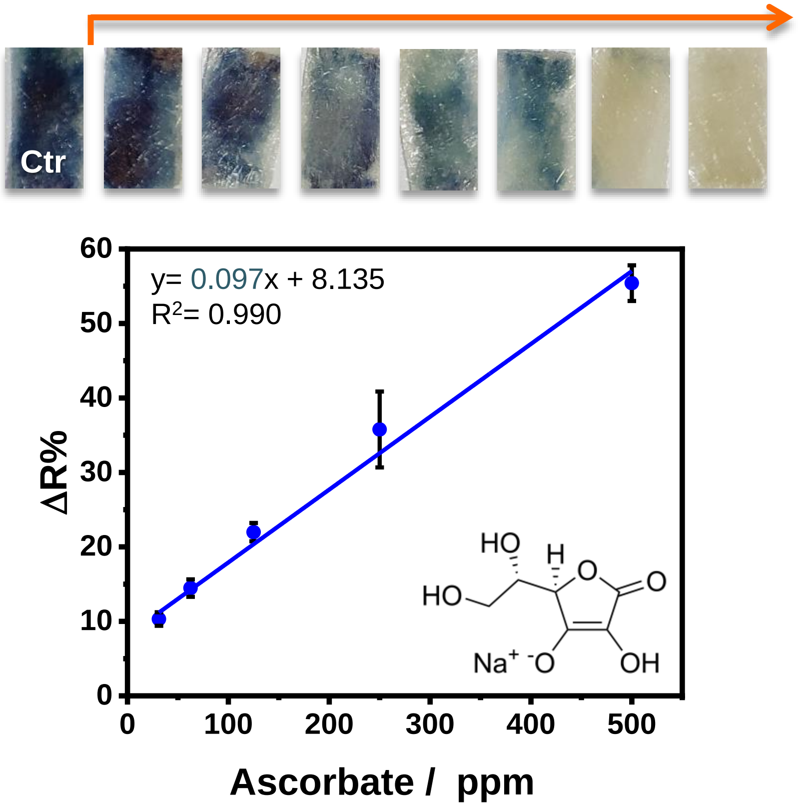
Ascorbic acid determination

L-Ascorbic acid (AA)



L.R.: 31- 250 ppm;
LOD= 6.5 ppm
RSD≤ 12%, n= 3

Ascorbate

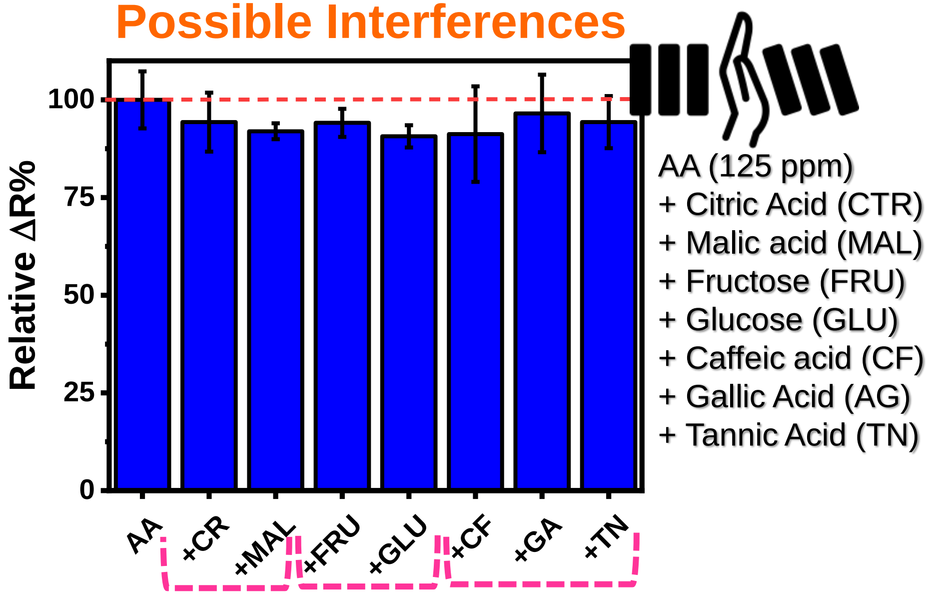


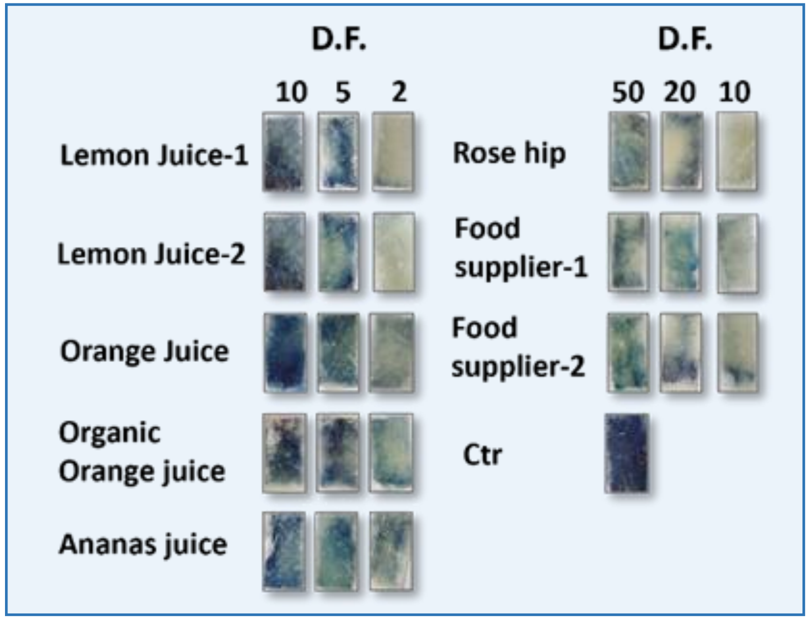
L.R.: 31- 500 ppm;
LOD= 8.9 ppm
RSD≤ 11%, n= 3

LIM: Colorimetric determination of Ascorbic Acid

Ascorbic acid determination in samples

Possible Interferences





Sample	Flip-PAD	std.dev.	Enzymatic Photom. kit	std.dev.	RELATIVE ERROR
	mg 100g^{-1}		mg 100g^{-1}		%
Lemon Juice-1	483.8	±32.6	545.3	±52.0	-11.3
Lemon Juice-2	1316.4	±48.9	1397.7	±98.9	-5.8
Orange Juice	24.6	±0.9	27.3	±2.0	-9.7
Organic Orange Juice	60.2	±2.0	60.1	±5.5	0.3
Ananas Juice	18.5	±1.3	18.6	±0.5	-0.5
Rose hip	55884.2	±1680.2	53574.3	±1562.8	4.3
Food Supplier-1	8689.2	±320.6	9530.2	±811.8	-8.8
Food Supplier-2	1291.3	±150.8	1329.9	±110.9	-2.9

Recovery:
92 - 114 %
RSD ≤ 7 %, n=3